BBC

WHAT COMES NEXT FOR THE WEBB TELESCOPE

After deployment success, what will its first images show?

#202 MARCH 2022

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

THE AURORA EXPANDS

How increasing solar activity is bringing the Northern Lights ever further south

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Our view of how planets are formed just got a lot clearer

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The simple method to get more out of your time under the stars

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An astronomer's guide to weather forecasting

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Welcome

Exploring why the Northern Lights are heading south

There have been many reports of dramatic aurora displays by UK astronomers in the past few months, increasingly from areas further south which are not often treated to displays of the Northern Lights. It's a sign that auroral activity is on the increase, and on **page 38** aurora expert Dr Melanie Windridge explores what's behind these more powerful displays and how they are intimately linked to longer-term activity on the Sun. You'll also find an observer's guide to the many different forms an aurora display can take on **page 40**, to prepare you for your next Northern Lights expedition – perhaps your next view of the aurora could be close to home!

From space weather to our planet's weather, and the big influence it has on the success of our observing. On **page 61**, Pete Lawrence looks at how to read weather forecasts and charts if you're an astronomer, in a bid to avoid rain and cloud, as well as some less well-known effects the atmosphere can challenge us with.

When weather doesn't cooperate, there's not much we can do about it. However, there are other factors that conspire to interrupt our observing plans which we can control. Long-time Canadian astronomer Ron Brecher considers these – such things as exposure to the wind and how to make the most of available time – on **page 28**, to put forward the Make-or-Break equation, an adaptation of the famous Drake equation. It's a light-hearted view of observing and imaging that could help you spend more time out under the stars.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 24 March 2022.

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Overseas enquiries: PO Box 3320,
3 Queensbridge, Northampton, NN4 7BF, UK
Editorial enquiries
BBC Sky at Night Magazine, Our Media (an Immediate Group Company), Eagle House, Bristol, BS1 4ST

BBC Sky at Night Magazine ISSN 1745-9869 (USPS 24520) issue 202, March is published monthly by Immediate Media Co Bristol Ltd., Eagle House, Bristol, BS1 4ST, United Kingdom.
The US annual subscription price is $155.88. Airfreight and mailing in the USA by agent named World Container Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA.

US POSTMASTER: Send address changes to *BBC Sky at Night Magazine*, World Container Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434.
Subscription records are maintained at Immediate Media Bristol Ltd., Eagle House, Bristol, BS1 4ST, United Kingdom.

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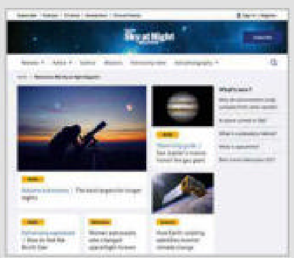
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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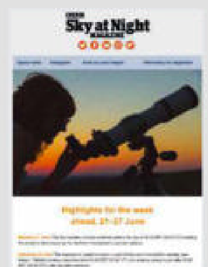

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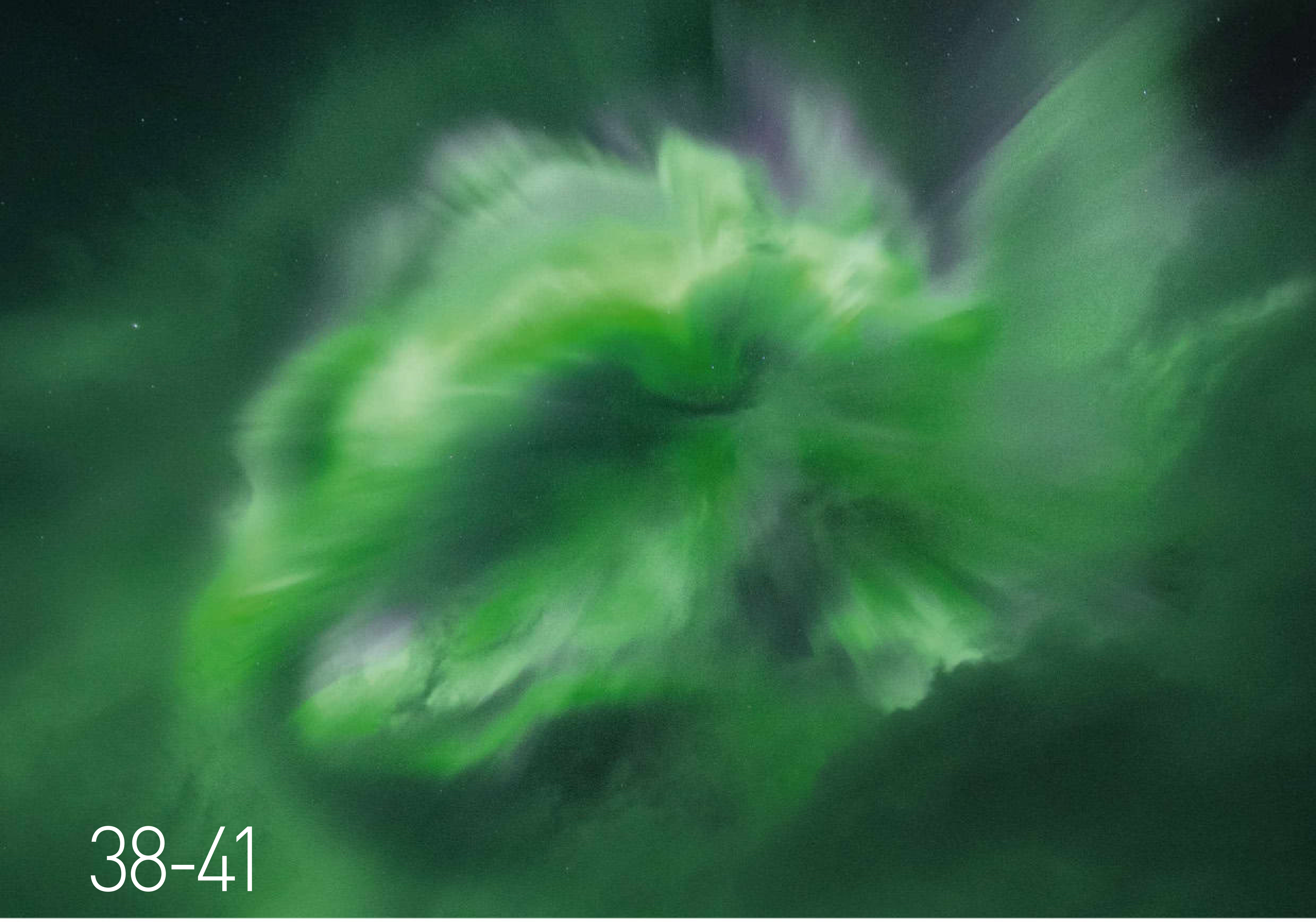
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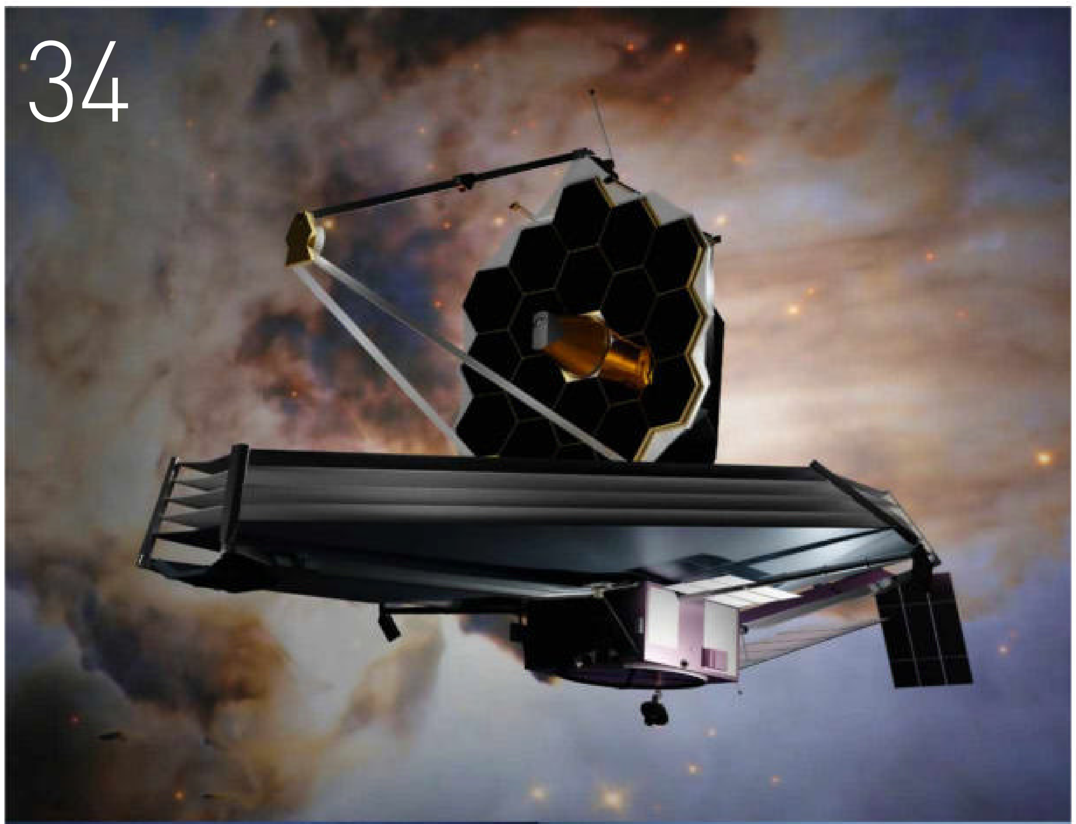
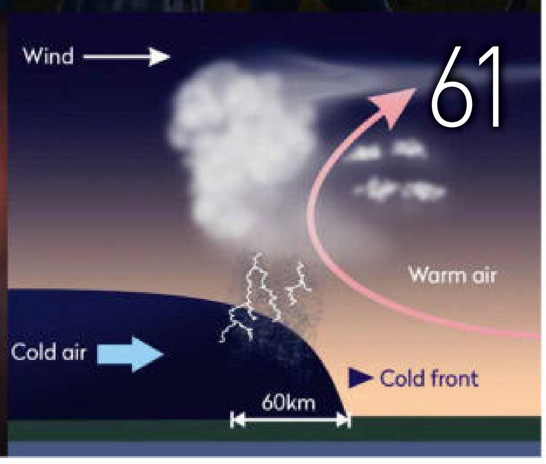
(C) = on the cover

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**





This month's contributors

Ron Brecher

Astronomer

"I hope readers find my take on the Drake equation useful for finding ways to increase the time doing what they love, whether that's observing or imaging." **Ron creates a formula for successful observing,** **page 28**

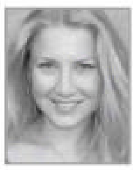
Ezzy Pearson

News editor

"It's really fascinating to see how much we can learn about young exoplanets, even when they're shrouded in dust." **Ezzy looks at new research into how exoplanets emerge from circumstellar discs,** **page 68**

Melanie Windridge

Plasma scientist



"It's really exciting to see solar activity picking up again; I loved asking UK aurora-spotters where they go, and seeing their fabulous photos." **Melanie explains the rise in aurora activity in the UK,** **page 38**

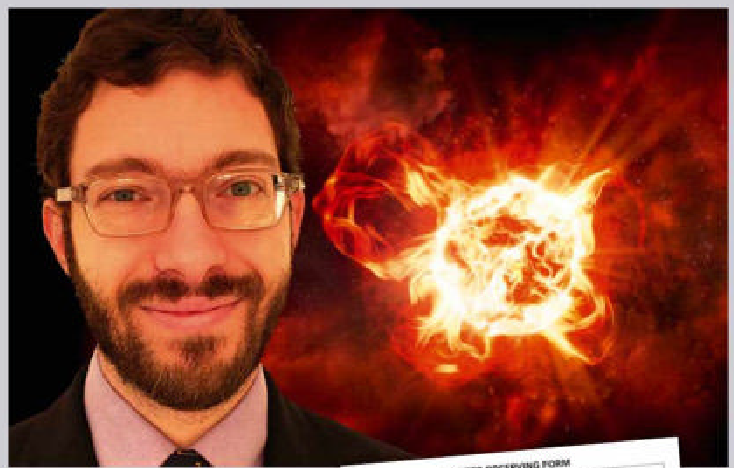
Extra content ONLINE

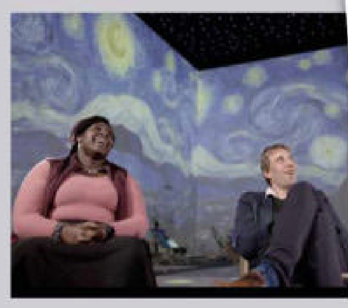
Visit **www.skyatnightmagazine.com/bonus-content/35LDAHR/** to access this month's selection of exclusive Bonus Content

MARCH HIGHLIGHTS

Interview: the science of exploding stars

Astrophysicist Or Graur reveals how supernovae are key to unravelling the secrets of the Universe.





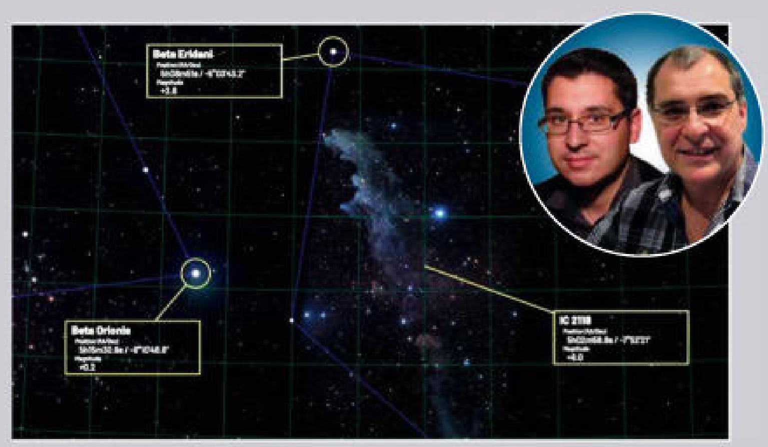
Watch *The Sky at Night: Dark Skies*

Maggie and Chris reveal how light pollution from towns and cities has a detrimental effect on our view of the night sky.

Plan your observing for the month ahead

Download extra charts to help you observe the planets and take this month's binocular and deep-sky tours.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

A WIGGLE AND A WAVE

A crystal-clear new portrait shows the twisted jets emitting from a wobbly protostar

GEMINI SOUTH TELESCOPE, 20 JANUARY 2022

Snaking through space, these curvy jets come from a young rotating star 10,000 lightyears away on the boundary of the constellations of Sagittarius and Ophiuchus.

With the aid of the adaptive optics instruments on board the Gemini South telescope at Cerro Pachón, Chile, which counteract the blurring effects of atmospheric turbulence, researchers have revealed these distinctive S-shape twin plumes continuously pouring from the protostar at the centre.

The jets are called MHO 2147 and are a sign the star, cloaked in a fog of dust and molecular gas, is getting started in its formation. Scientists think the jets' wiggly path may be the result of precession: the gravitational wrench of nearby companion stars causing the protostar to wobble slowly like a spinning top.

MORE **ONLINE**
A gallery of these and more stunning space images

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA

◁ More harmony than hostility

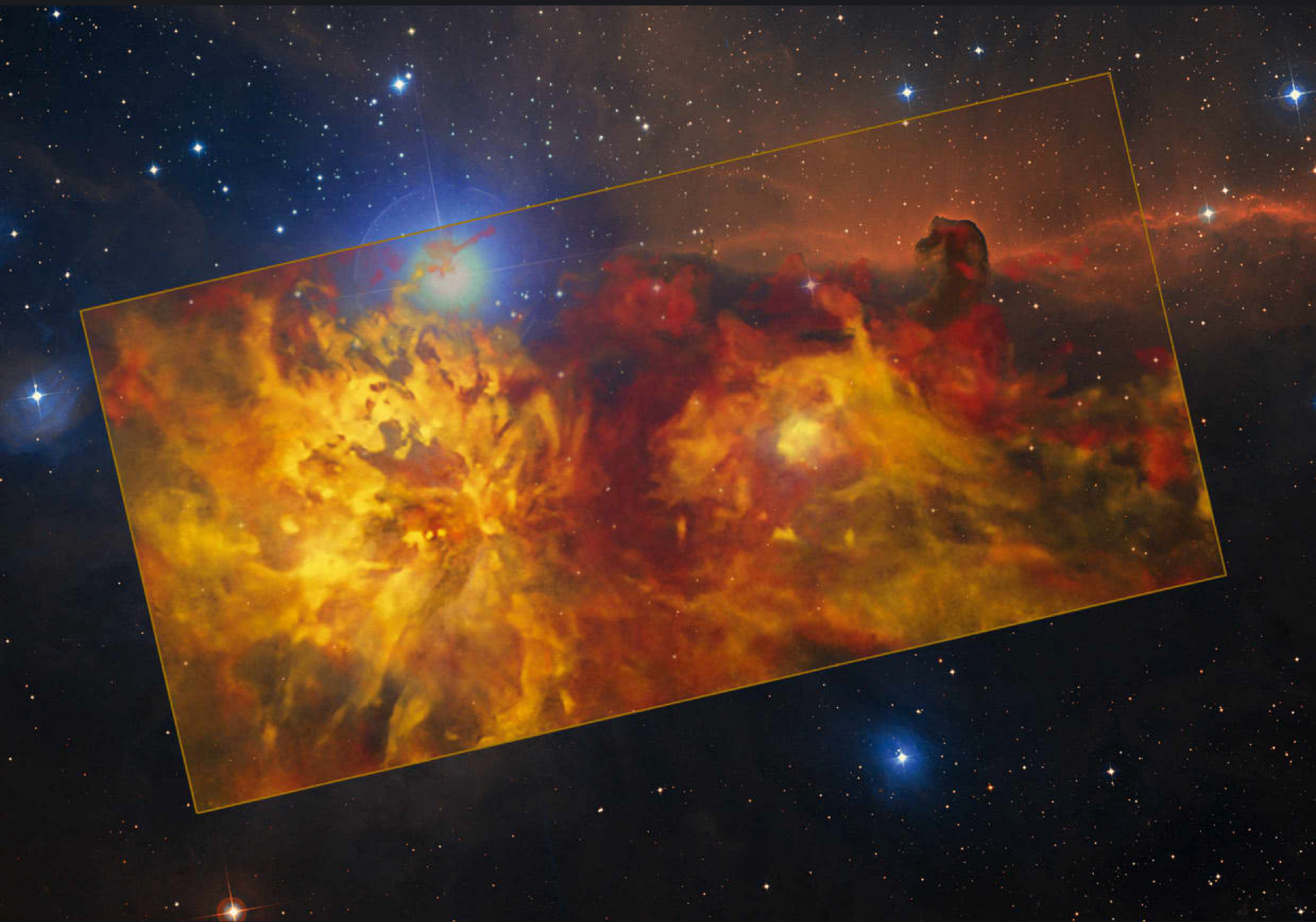
HUBBLE SPACE TELESCOPE, 24 JANUARY 2022

Likened by some to a galactic game of frisbee, what appears to be galaxies being ripped to shreds in a fierce skirmish is more likely – as head-on collisions are rare – a group peacefully coexisting and not interacting at all. Called NGC 7764A, the triplet sits roughly 425 million lightyears away in the constellation of Phoenix.

▽ New look at an old Flame

ATACAMA PATHFINDER EXPERIMENT (APEX) TELESCOPE, 4 JANUARY 2022

The Flame Nebula, NGC 2024, blazes bright in this image combining radio data (rectangle) with a visible light image (background). On the right, rising up from the 'flames' is the iconic dark Horsehead Nebula, while dazzling star Alnitak (Zeta (ζ) Orionis) lights the scene. Despite its fiery appearance in this rendering, the region is largely made up of very cold gas and dust.

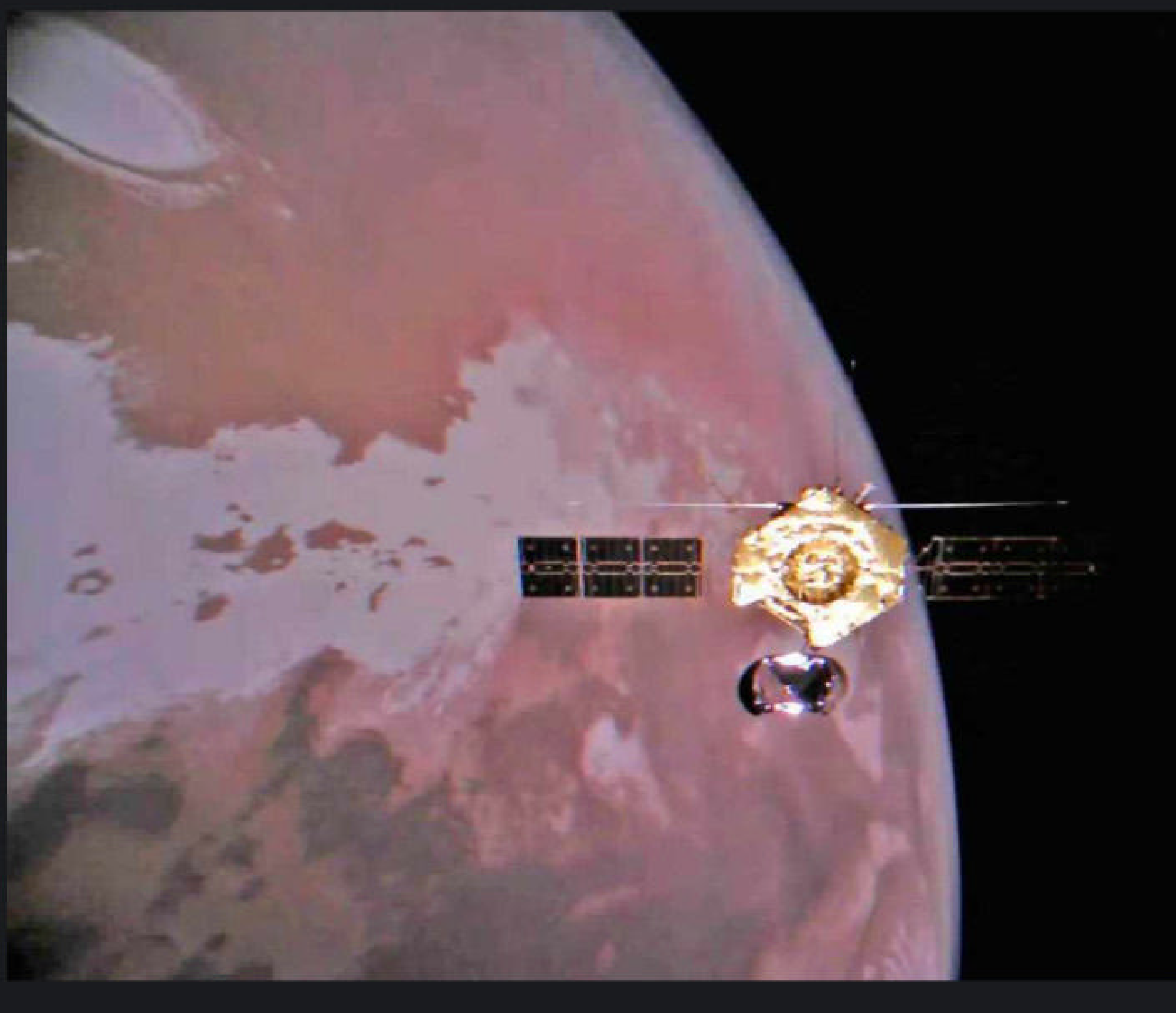


ESA/HUBBLE & NASA/J. DALCANTON/DARK ENERGY SURVEY/DOE/FNAL/DECAM/CTIO/NOIRLAB/NSF/AURA/
ESO, ESO/TH. STANKE & ESO/DIGITIZED SKY SURVEY 2, NASA/JPL-CALTECH/SWRI/MSSS/KEVIN M. GILL, CNSA

△ Perfect storm

JUNO, 29 NOVEMBER 2021

Two massive rotating storms are captured in exquisite detail in this bird's eye view from NASA's Juno probe. Taken from an altitude of 6,140km, it shows details as small as 4km across. Although the white 'pop-up' clouds in the lower storm look comparatively small, they are around 50km long. Juno's microwave radiometer recently revealed the planet's storms extend far deeper than anticipated, even by hundreds of kilometres.



A selfie that's out of this world ▷

TIANWEN-1, 1 JANUARY 2022

This incredible shot of China's Tianwen-1 above Mars's ice-covered north pole was captured by a small camera released by the orbiter. Tianwen-1 has been mapping the Red Planet since February 2021, travelling 475 million kilometres and sending back 540 gigabytes of data. Down on the surface is the Zhurong rover it successfully deployed last May, which has since covered more than 1.4km.

The latest astronomy and space news, written by Ezzy Pearson

BULLETIN

Webb reaches its final destination

The space telescope has saved most of its fuel on the journey, extending the mission

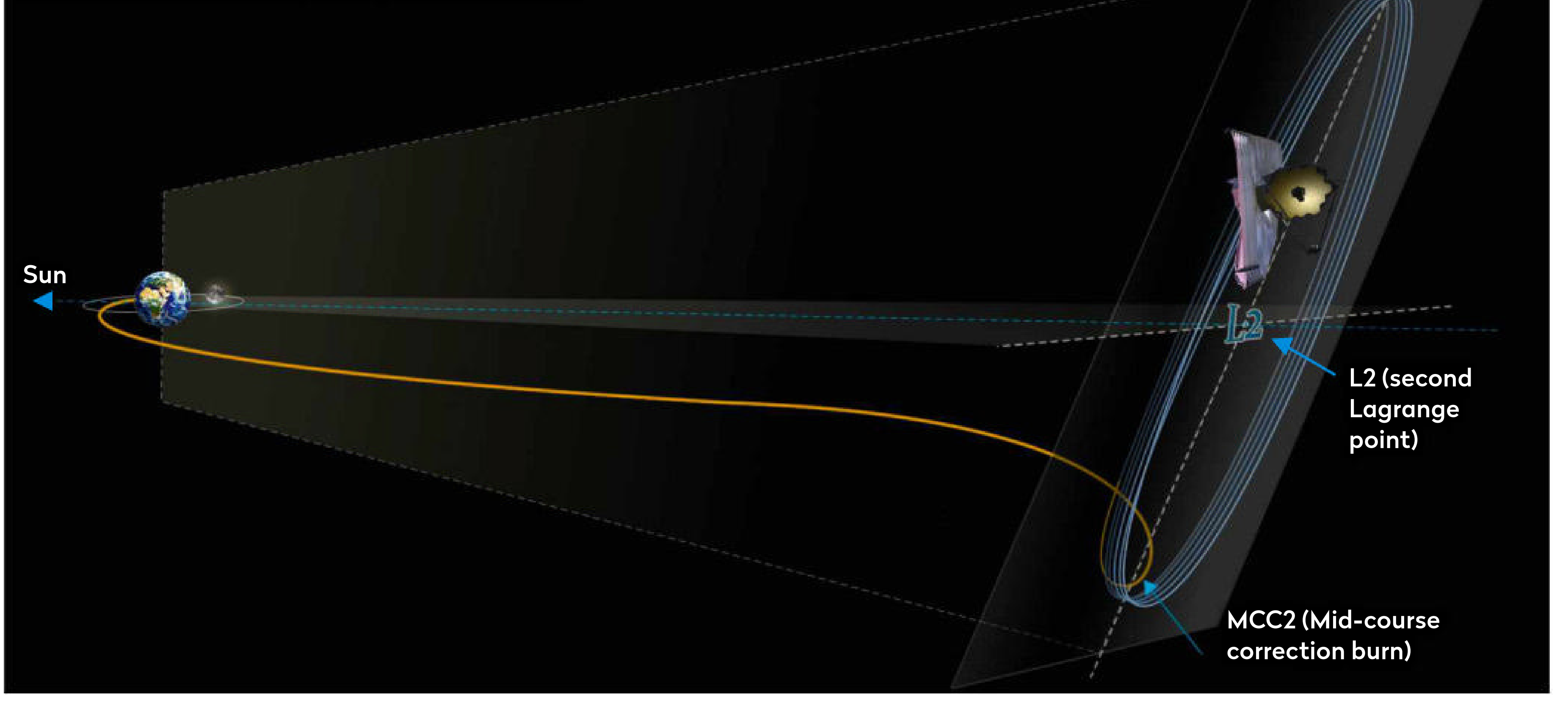
The James Webb Space Telescope (JWST) arrived at its final destination on 24 January at 7:05pm UT.

Webb is an infrared telescope with a 6.5m-wide mirror, making it the largest one ever deployed in space when it launched on 25 December 2021. A month later, it arrived at the gravitationally stable second Lagrange point (L2), located 1.5 million km from Earth. JWST fired its thrusters for five minutes to add around 1.6 metres per second to its speed. Though little more than a walking pace, this was all that was needed to put it into its final 'halo' orbit, moving in an ellipse around the L2 point.

This mid-course correction burn occurred a day later than scheduled, as both the launch and previous two course corrections had been so precise that hardly a nudge was needed to achieve its final orbit. Thanks to this accuracy, Webb was able to save a huge amount of fuel that can now be used in its operational phase, potentially extending the mission by decades.

"JWST's success is a tribute to all the folks who spent many years and even decades to ensure it," says Bill Ochs, JWST's project manager, who is now leading the telescope team as they spend the next five months setting it up. They had achieved the first step of establishing the high-speed data connection at the time of going to press.
https://webb.nasa.gov/

▸ **Turn to page 34 to find out more about what's in store for the JWST over the next five months**



JWST's orbit is 250,000km to 832,000km away from the L2 point. This helps to avoid power disruptions from passing through Earth's shadow

Comment
by Chris Lintott

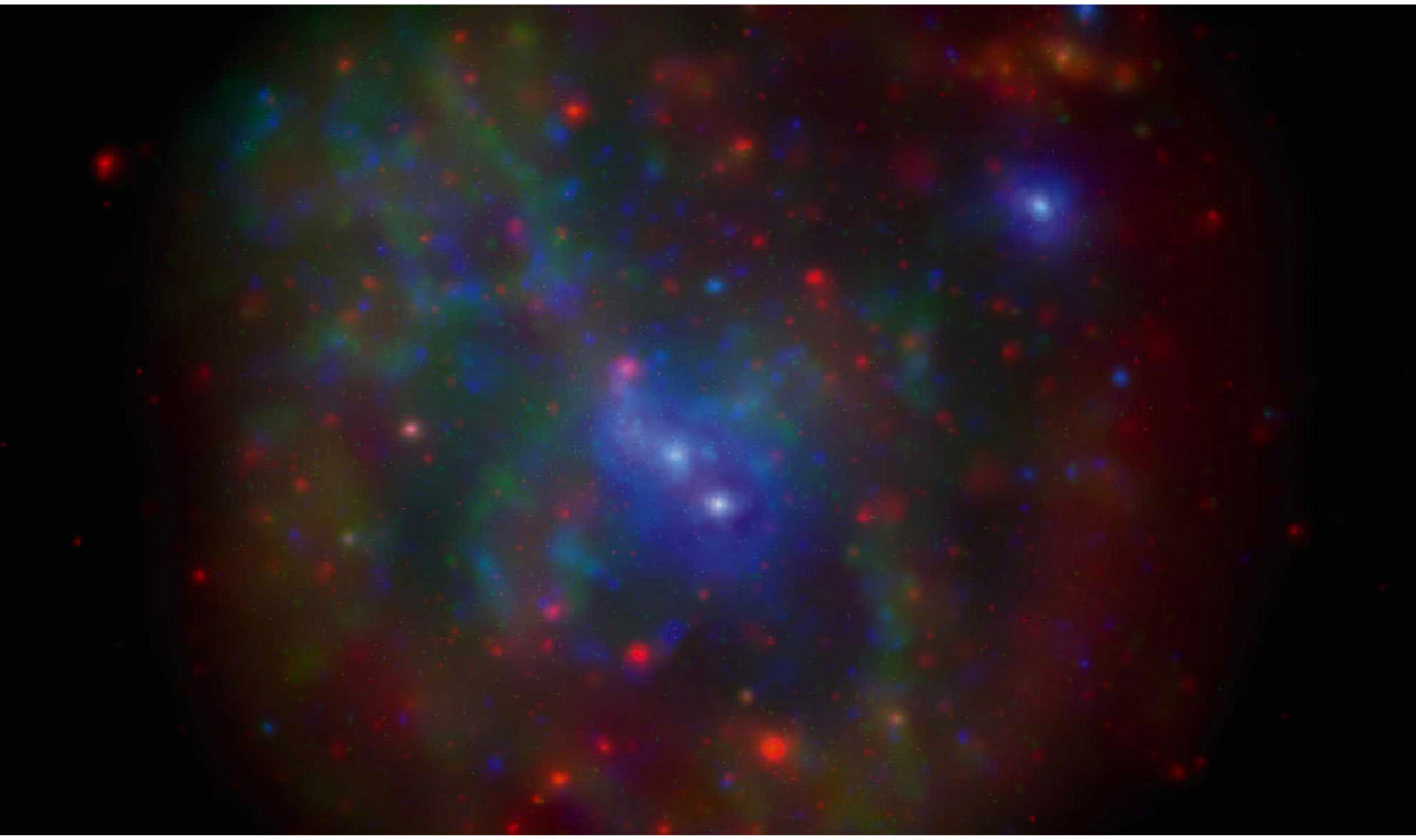
There are moments in life where you stop, astonished, by what you've just managed to do. It could be the tennis shot that sings off the strings, or when you catch all three of the glasses falling from the kitchen cupboard!

A similar feeling of bewildered excitement fills astronomers right now. The incredible JWST team have just played the game of their lives, executing the complex and scary sequence required to unfold the telescope and get it into position. As you read this, starlight is hitting JWST's mirrors, which are slowly being calibrated.

Because of this brilliance, it's slowly sinking in that we really are going to get to see the early Universe and the hearts of stellar nurseries. We really are going to get all that data on nearby exoplanets. After years of anxiety, we might just need a few months to grasp that it's really happened, that's all.

Chris Lintott co-presents *The Sky at Night*

STEVE SABIA/NASA GODDARD



▲ An image of our Galaxy's core made from X-ray observations by the Swift Observatory from 2006-13, with Sagittarius A* at its centre

NASA/SWIFT/N. DEGENAAR, NASA/CALTECH-JPL/MSSS, CFA/LEAH HUSTAK (STSCI), MARK MYERS/ARC CENTRE OF EXCELLENCE FOR GRAVITATIONAL WAVE DISCOVERY (OZGRAV)

Milky Way's black hole reveals erratic nature

Bright bursts from Sagittarius A* have waxed and waned for years

The black hole at the heart of the Milky Way erupts unpredictably and chaotically, a new study looking at over 15 years of data has found.

Known as Sagittarius A* (Sgr A*), the black hole at the centre of our Galaxy lies more than 26,000 lightyears from Earth, and is around four million times the mass of the Sun. The hot gas and dust around the black hole means it glows brightly at radio, X-ray and gamma ray wavelengths. Astronomers have known for decades that over the timescale of a day the emissions will suddenly flare, increasing in brightness by ten to a hundred times, but weren't sure how this flaring behaved over longer time spans.

To investigate this, Alexis Andrés, a postgraduate student from the University of Amsterdam, looked at data taken by the Neil Gehrels Swift Observatory, a telescope which has been looking for gamma ray bursts since 2006.

"The long dataset of the Swift Observatory did not just happen by accident," says Nathalie Degenaar, who requested the specific measurements from Swift when she was a PhD student and became Andrés's supervisor at the University of Amsterdam. "Since then, I've been applying for more observing time regularly. It's a very special observing programme that allows us to conduct a lot of research."

This data showed that Sgr A* had a high rate of flares from 2006 to 2008, which then dropped off before rising once again in 2012.

"How the flares occur remains unclear," says Jakob van den Eijnden from the University of Oxford. "It was previously thought that more flares follow after gaseous clouds or stars pass by the black hole, but there is no evidence for that yet. And we cannot yet confirm the hypothesis that the magnetic properties of the surrounding gas play a role either."

The team hope to uncover more about the flare's changing rate by monitoring Sgr A* using Swift over the next few years. This should reveal whether a passing cloud or an as yet unknown phenomenon is causing this fitful behaviour at our Galaxy's heart.
https://swift.gsfc.nasa.gov/

Curiosity's samples of ancient Martian rock, recovered from Gale crater, highlight the Red Planet's unusual carbon cycle

Carbon yields clues about ancient Mars

Past life on Mars could explain the low levels of carbon-13

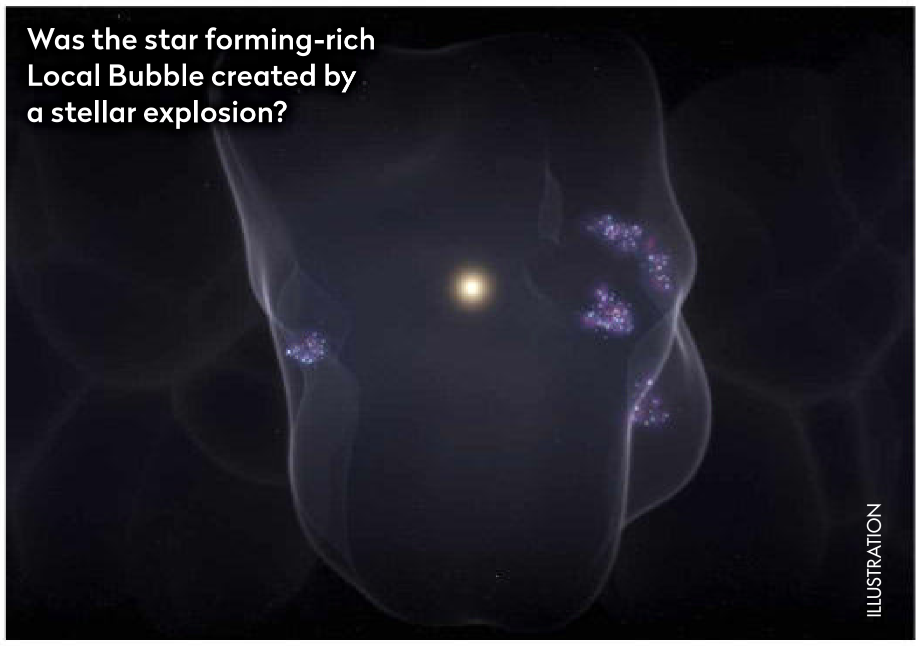
After a decade examining the Martian surface, the Curiosity rover has now given an insight into the life of carbon on ancient Mars, hinting at which geological – and perhaps even biological – processes shaped the planet.

The rover has been measuring the ratio of carbon-12 to carbon-13 on the planet, a value set during the Solar System's creation, but which changes over time due to all manner of geological, biological and cosmic processes. Curiosity found several areas of depleted carbon-13. There are three possible explanations: Mars passed through a Galactic cloud which deposited the carbon; ultraviolet radiation broke apart carbon dioxide in the atmosphere; or, ancient microbes produced and consumed methane.

"All three possibilities point to an unusual carbon cycle, unlike anything on Earth today," says Christopher House from Penn State University, who led the study. "But we need more data to figure out which of these is the correct explanation." **www.psu.edu**

Cosmic bubble blown by supernovae

Earth is surrounded by a 1,000 lightyear-wide void, called the Local Bubble, the edge of which is marked by thousands of young stars. Now, thanks to new simulations, astronomers might finally know what caused it – a series of supernovae beginning 14 million years ago which pushed gas outwards, creating dense regions ripe for star formation.



Was the star forming-rich Local Bubble created by a stellar explosion?

Using observations from the Gaia observatory, astronomers could map out the bubble's irregular shape and determined that it is drifting through the Galaxy at about 6.5km per second. The simulations used these two pieces of information to reveal that the bubble has been carved out by around 15 supernovae over millions of years.

"When the first supernovae that created the Local Bubble went off, our Sun was far away from the action," says João Alves from the University of Vienna, who took part in the study. "But about five million years ago, the Sun's path through the Galaxy took it right into the bubble, and now the Sun sits – just by luck – almost right in the bubble's centre." **https://hubblesite.org**

NEWS IN BRIEF

Eccentric mergers

For the first time, astronomers have detected the merger of two 'eccentric' black holes with highly elliptical orbits using LIGO (the Laser Interferometer Gravitational-Wave Observatory). The odd orbits are a sign they're consuming other black holes, and could explain previously detected black holes that were much larger than expected.

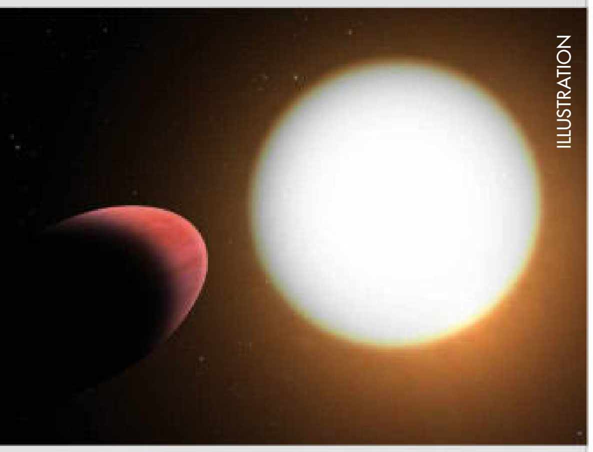
Monitoring space debris

Kielder Observatory in Northumberland is joining forces with 'space situational awareness' company Northern Space and Security Limited to battle a growing problem of space junk. Four cameras are being installed at the observatory to track orbital debris from the dark-sky site to help avoid future collisions.

InSight takes a break

The InSight Mars lander was forced to enter safe mode in a Martian dust storm on 7 January. Thankfully, the skies cleared and it could return to normal operations on the 19th unscathed, if a bit dirtier than before.

NEWS IN
BRIEF



Rugby ball planet

Tidal forces have pulled exoplanet WASP-103b into the shape of a rugby ball. The CHEOPS Space Telescope has measured the dip in brightness as the planet passes in front of its star accurately enough that astronomers could make out the world's strange shape from the fluctuating light pattern.

Sun circled by dust?

The Sun may have once had rings which prevented Earth from becoming a 'super-Earth', as are found around a third of other Sun-like stars. Dust rings are seen around several growing planetary systems, so astronomers simulated them and found they created systems much like our own, with its diminutive terrestrial planets.

China to explore lunar south pole

China has announced it is officially heading to the lunar south pole with missions Chang'e 6 through 8, including a sample return mission. The region is thought to be home to water ice deposits, making it the most promising spot to set up a future lunar station.

ESA, NASA/FRANK MICHAUX, ALMA (ESO/NAOJ/NRAO) B. SAXTON (NRAO/AUI/NSF)

Artemis 1 delayed until spring

Testing continues, but progress is slower than expected

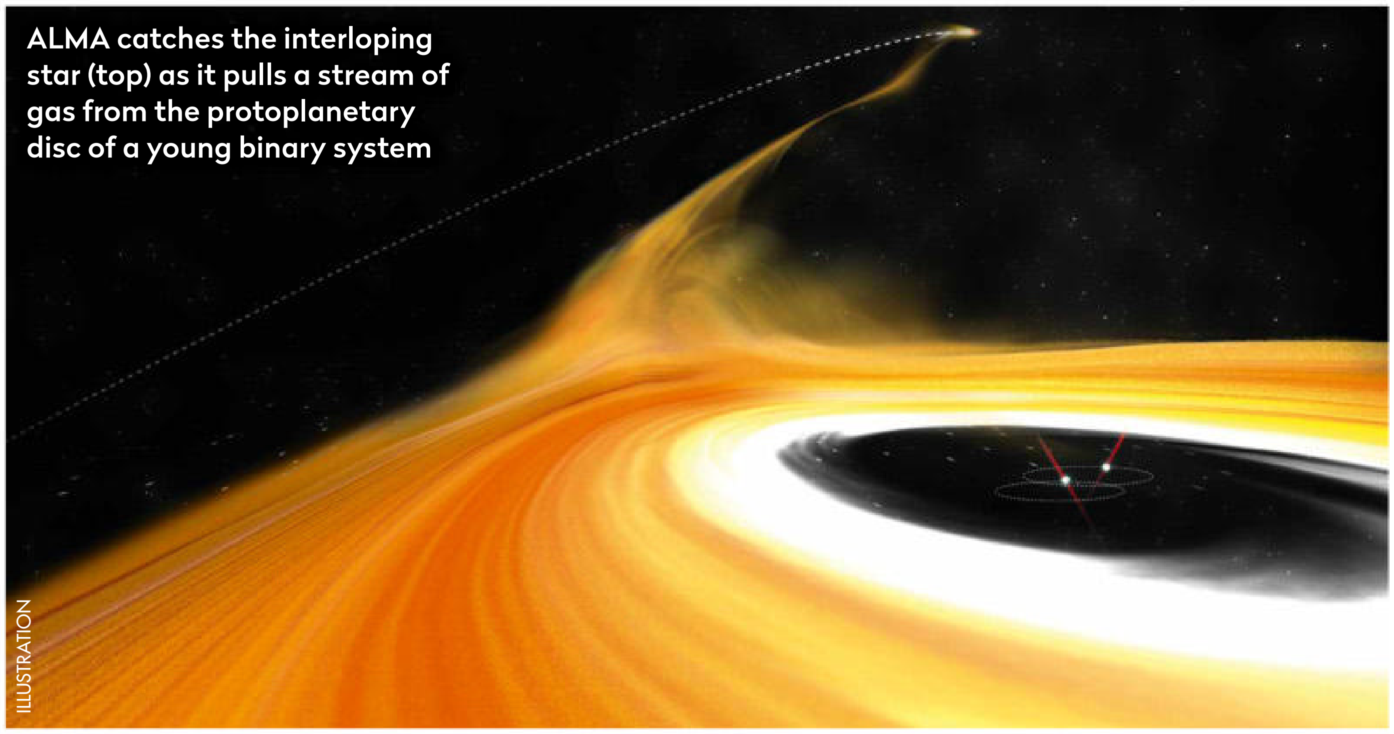
The Artemis 1 mission launch has been held back until 12 March at the earliest, while a later launch date is looking increasingly likely. This latest delay comes after an engine computer had to be replaced in late 2021, and means the Space Launch System (SLS) rocket assembly will not be moved on to the launch pad until at least mid-February. While this would make a March launch possible, there is little room to deal with any issues that arise, increasing the possibility of a launch in April or later.

NASA's Artemis 1 mission will serve as a dress rehearsal for future flights to the Moon and will spend several days in lunar orbit before returning to Earth. Despite the delay, NASA finished testing the core stage on 14 January and completed a countdown rehearsal on 24 January, demonstrating that the launch software is working correctly.

www.nasa.gov


Artemis 1 has been setback after an engine computer replacement

Stellar intruder buzzes infant binary



ALMA catches the interloping star (top) as it pulls a stream of gas from the protoplanetary disc of a young binary system

A trespassing star has been caught in the act of flying past a growing young stellar pair, in a detection made by ALMA (the Atacama Large Millimeter/submillimeter Array). Such stellar flybys have often been seen in computer simulations, but happen so quickly that no one has witnessed one taking place until now.

The flyby occurred in the Z Canis Majoris (Z CMa) binary star system, a young system only a few hundred thousand years old, which is still surrounded by its protostellar disc of dust. When the star flew past it pulled the debris disc out of shape, creating a chaotic stream of dust and gas. By analysing this pattern, the team were able to determine the intruder was an unrelated star, and not part of the same group as Z CMa.

"What we now know with this new research is that flyby events do occur in nature and that they have major impacts on the gaseous circumstellar discs surrounding baby stars, which are the birth cradles of planets," says Nicolás Cuello from the Université Grenoble Alpes, who helped with the study.

https://public.nrao.edu

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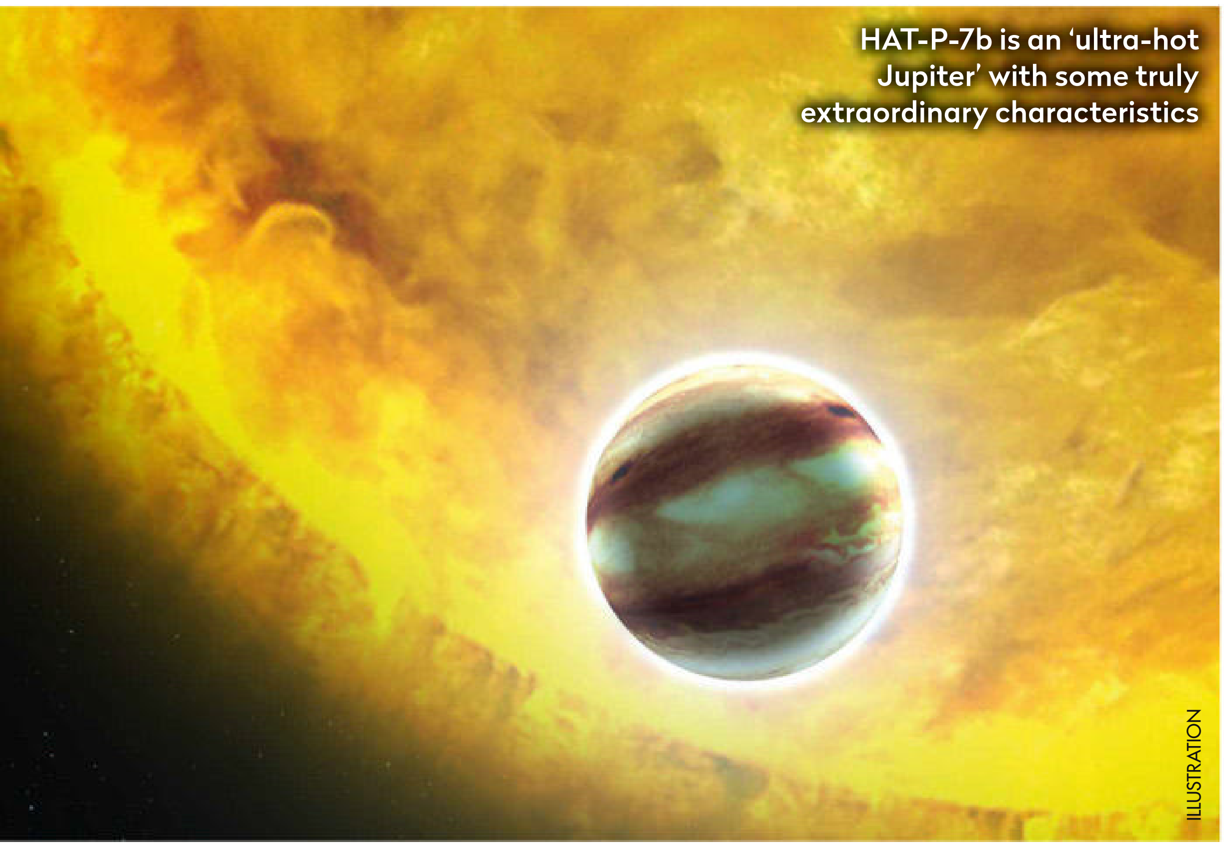
CUTTING EDGE



HAT-P-7b is an 'ultra-hot Jupiter' with some truly extraordinary characteristics

The planet with a sapphire sky

This ultra-hot exoplanet is heated to such an extent that its atmosphere is one of the richest in elements yet seen

HAT-P-7b (or Kepler-2b) is an exotic exoplanet. Discovered in 2008, it has a radius greater than that of Jupiter and an orbital plane so tilted relative to its star (108°) that it's nearly in a polar orbit. But what makes the planet truly exceptional is how hot it is. HAT-P-7b hugs its bright, A-class star so tightly that its orbit takes less than three days – it's over 20 times closer to its sun than Earth is to ours. Day-side temperatures on the planet are calculated to be regularly above 2,200°C – similar to many stars themselves. Fittingly, HAT-P-7b sits in a class of planet known as 'ultra-hot Jupiters'.

It's also one of the darkest planets ever observed, with an albedo (surface reflection) of less than 0.03 – roughly that of a lump of charcoal. The planet is so black it absorbs more than 97 per cent of visible light shining onto it. Chemical models of its atmosphere predict that on its slightly cooler night-side the crystalline aluminium oxide mineral 'corundum', the same substance as rubies and sapphires, condenses as clouds.

The enormous heating has also inflated the planet's upper atmosphere into a puffy envelope and this, combined with the brightness of its sun, means that HAT-P-7b is an ideal target for studying with transmission spectroscopy. In this technique, the starlight that passes through a planet's atmosphere is analysed to reveal information about the chemicals that have become imprinted on it.

Aaron Bello-Arufe at the National Space Institute, part of the Technical University of Denmark, and his colleagues are the first team to analyse HAT-P-7b using transmission spectroscopy, and they've discovered even more astonishing details.

High-speed metal

They used the High Accuracy Radial velocity Planet Searcher for the Northern hemisphere (HARPS-N), a high-resolution spectrograph on the 3.6m Telescopio Nazionale Galileo at the Roque de los Muchachos Observatory on La Palma in the Canary Islands. They observed a single transit of HAT-P-7b across its star on the night of 18 December 2020 and recorded the spectrum of light passing through its atmosphere.

They reported detecting a whole host of elements including iron, calcium, magnesium, sodium and chromium – possibly titanium too.

Bello-Arufe's work has marked HAT-P-7b out as one of the exoplanets with the greatest number of atomic species detected in its atmosphere. And this metal-laden air is testament to just how hot the planet is.

"The planet is one of the darkest ever observed, with a surface brightness of less than 0.03 – roughly that of a lump of charcoal"

But Bello-Arufe's team also discovered that the spectroscopic lines of these atmospheric atoms are significantly blue-shifted in their observations, revealing just how fast the atmosphere is churning in the heat. They calculated wind speeds of over 2km per second – some 7,200 km/h – as the expanding day-side air rushes towards the cooler night-side. What's more, because different atomic species are expected at different altitudes, the team was able to construct a rough wind-speed profile. The next step, they say, would be to use emission spectroscopy to study the chemical composition of the day-side of the planet.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Mining the Ultra-Hot Skies of HAT-P-7b: Detection of a Profusion of Neutral and Ionized Species* by Aaron Bello-Arufe et al.
Read it online at: arxiv.org/abs/2112.03292

How to build a Universe

A group of astronomers have created over 4,000 universes using computer simulations

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Cosmologists have it hard: creating a 'universe' is expensive and difficult, and even if you do manage to play God, you have to wait billions of years for the outcome of the experiment. The cosmologists' solution is to use powerful computers to create simulations that allow us to see what happens if you try things like changing the amount of mass in a universe.

The trouble is that it's hard to work out which bits of the Universe you can simulate. Creating a realistic view that can be compared with the images and data gathered from today's telescopes requires keeping track of processes that take place on a large range of scales, from the forces affecting the Universe's expansion to the chemistry occurring in star-forming clouds. It can be done, partly, through clever programming, but it also requires the use of a supercomputer – in the case of the CAMELS (Cosmology and Astrophysics with MachinE Learning Simulations) project, there is a massive supercomputer known as 'Popeye-Simons' in San Diego. With it the CAMELS researchers have created 4,233 universe simulations. For some, only the behaviour of the matter moving under gravity is followed – essentially, these are skeleton universes made only of dark matter – but for more than half of the simulations the computer has tried to follow the physics of the gas and stars too.

Fitting it all in

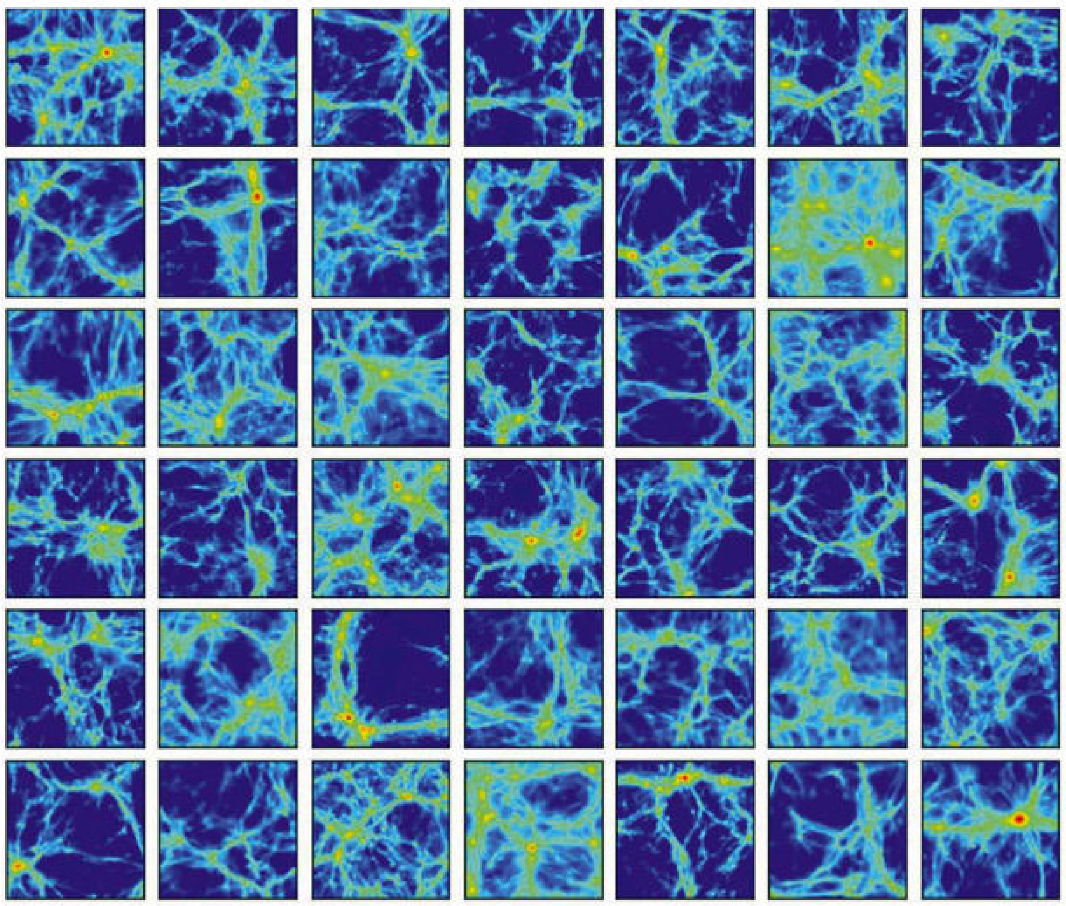
Each universe is different, as various approaches are used to solve the problem of cramming a universe's worth of physics into a code that can be run on a computer. But a crucial set of simulations alters the physics, either changing the density of matter in a universe simulation (how clustered it is) or altering parameters that control how efficiently supernovae and activity associated with a galaxy's central black hole pump energy into the surroundings.

The resulting data, and the maps and simulated observations generated from it, have been made public by the CAMELS team. It'll be especially useful for observations made with ESA's Euclid telescope, which is expected to launch in 2023. Intriguingly, the team has also spent a lot of time making its virtual universes accessible to machine-learning algorithms. These can be used to simulate the work of the simulators, saving time and money by predicting what universes with properties in between those already modelled might be like.

"Various approaches are used to solve the problem of cramming a universe's worth of physics into a code that can be run on a computer"

That opens up new angles for investigation. In the simulations, we know the true mass of a galaxy, so the team has used the CAMELS data to train an algorithm that can predict a galaxy's mass based on its properties. By turning that on the Milky Way, the team can find a new way to measure the properties of our own, real, Galaxy, from studying millions of artificial equivalents.

The possibility of understanding how much we can say about cosmology, the behaviour of the Universe as a whole, from the study of a single galaxy is exciting. Simulations used in this way don't just provide a check on our observations, but suggest new ways we can use our telescopes.



▲ **Each of the CAMELS project's simulations reveals something different, in this case the variation in gas densities in a selection of model universes**

Chris Lintott was reading... *The CAMELS project: public data release* by Francisco Villaescusa-Navarro.
Read it online at: arxiv.org/abs/2201.01300

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT


ILLUSTRATION

In the January episode of *The Sky at Night*, **Tim Stevenson** highlighted how light pollution is a growing problem for radio astronomers

▲ **Concerns are being raised that observations by the Square Kilometre Array (SKA) – the world's largest radio telescope (as seen here in an artist's impression) – will be hindered by light pollution from satellite megaconstellations**

While radio astronomers are used to handling some radio interference from terrestrial sources, and a few air or space borne transmitters, the new megaconstellations of internet access satellites – which number in the thousands – are a much greater problem.

In the January episode of *The Sky at Night* I talked a bit about this new threat, but as it's hard to explain the problem of these new satellite systems in a short TV interview, I will go into more detail here. It's a complicated issue and it will help readers if I can give them a bit more background on the subject, so they can begin to understand the impact on the relatively young science of radio astronomy – a field which, after all, will have the greatest chance of discovering advanced extraterrestrial civilisations.

Radio astronomy is protected by international law, through the ITU (International Telecommunications Union) and its Radio Regulations. These Radio Regulations define certain 'silent' frequency bands, where transmitters are not allowed to operate. Although this was adequate for the early years of this new branch of astronomy, the Universe 'speaks' in a very broad range of frequencies and therefore modern radio astronomy needs to often 'listen' in bands assigned to transmitting users. This is possible by building telescopes in very remote and protected areas of the planet where the use of the radio spectrum is minimal. In these 'Radio Quiet Zones', all radio transmitters are banned. Indeed, mobile phones, laptops and even smart watches are not allowed. The difficulty is that, even in Radio Quiet Zones, we can't escape air- and space-borne transmitters and have to cope with them.

The power of radio astronomy

Radio observations of the Universe can inform us about a vast variety of processes, in galaxy, star and planet evolution. So choosing one example to illustrate the impact of the new radio interference

SKAO, NASA, BBC

Tim Stevenson has over 40 years experience as an engineer in space and ground-based astronomy and space science

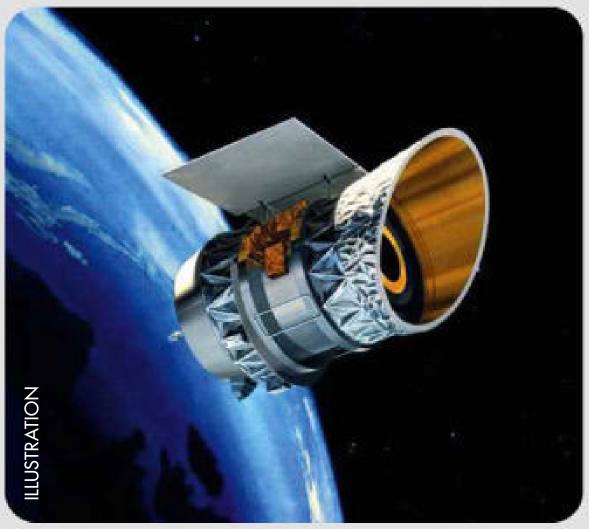
sources does not do justice to the scale of science that Square Kilometre Array (SKA) radio telescopes can do, but here goes.

The Universe is mostly empty, but gas is relatively common, and gas molecules emit radio signals which are unique to them. Readers of this magazine will be familiar with the concept of redshift, where light emitted by something moving quickly has its frequency shifted, and displacement applies to radio signals as well as optical light. This means that the further away – hence the further back in time – we look for a particular molecule, the lower its frequency will be. So what was a single frequency of interest has become a range of frequencies. For molecules that are particularly important for star evolution, we want to be able to visualise their distribution over time/distance and effectively create a map of the evolution of the Universe over time. The example I gave on the show was carbon monoxide (CO). For such molecules, in distant galaxies where the SKA has the power to look, the frequency is found in a region where the satellite megaconstellations are now transmitting strongly and we are becoming blind to certain times in the past (and therefore stages of stellar evolution), which is extremely worrying. That's why we are raising awareness on the issue.

Looking back: The Sky at Night

31 March 1985

On *The Sky at Night* episode that aired back on 31 March 1985, Patrick Moore took a look at a raft of discoveries being made using data from the Infra-Red Astronomical Satellite (IRAS) – the first infrared space telescope. A joint project between the US, Netherlands and the UK, the satellite launched on 25 January 1983 and operated for 10 months, observing 250,000 targets.



▲ **The IRAS paved the way for future infrared space telescopes, including JWST**

The first observatory to fly above Earth's infrared-absorbing atmosphere, IRAS opened a new window on the Universe. It made the first ever detection of solid material around the discs of stars – namely Vega and Fomalhaut. Thought to be sand-sized dust at the time, it was an early indication of the circumstellar discs that modern day observatories are imaging today. (To find out how exoplanets grow, see page 68).

The telescope also made several serendipitous discoveries, as it uncovered six of the 22 comets found that year, picking up the infrared radiation from their 'warm' tails against the background of space.

Despite only operating for 10 months, IRAS achieved much. Its legacy was continued by the many infrared observatories that followed, such as Spitzer and the Wide-field Infrared Survey Explorer (WISE), all leading up to the James Webb Space Telescope (see pages 11 and 34).

The Sky at Night

The Sky at Night team are taking a break this month and will return in April for more astronomy and spaceflight news and observing advice. In the meantime, young astronomers can catch up on *Out of This World*, a wonderful 10-episode guide to spaceflight hosted by Dr Maggie Aderin-Pocock and her daughter Lori. The series features special guests and covers spacecraft design, living in space, the search for extra-terrestrial life and the robotic rovers exploring the bodies of our Solar System. Watch the entire series via **bbc.co.uk/iplayer**

▲ **Dr Maggie Aderin-Pocock and her daughter Lori present *Out of this World***

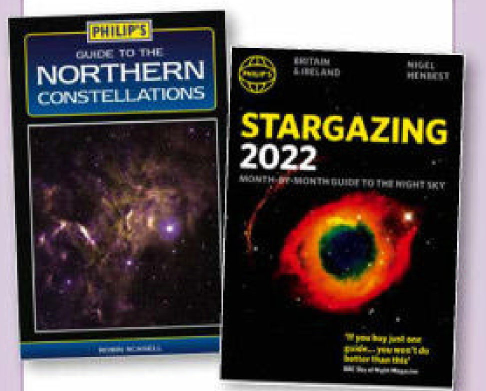
Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: two Philip's titles



The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2022* and Robin Scagell's *Guide to the Northern Constellations*

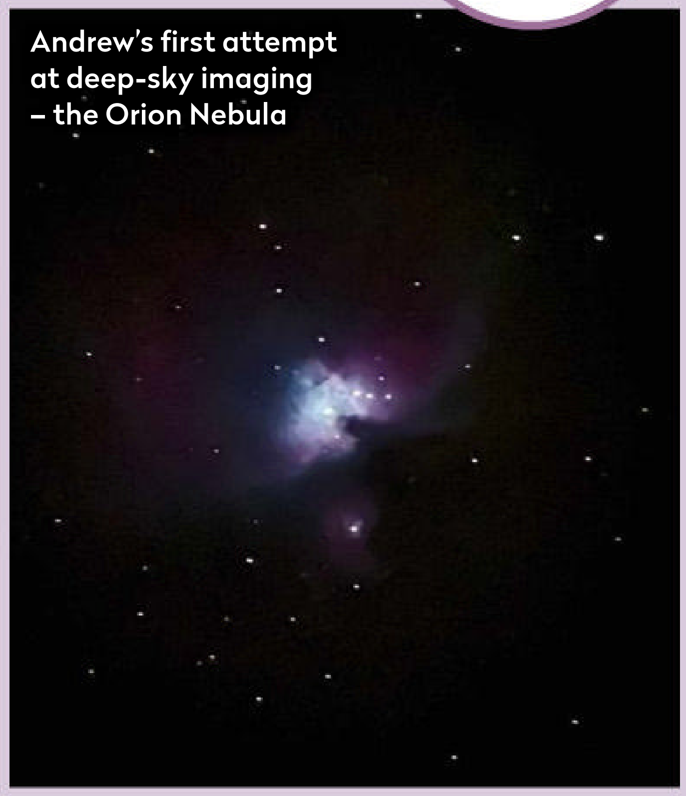
Winner's details will be passed on to Octopus Publishing to fulfil the prize

Deep-sky starter

I enjoy reading the magazine every month as an ongoing gift subscription. Inspired by some of your introductory astrophotography articles I thought it would be interesting to share my first attempt at a deep-sky object, in this case the Orion Nebula, M42 and M43. I'm mainly into observational astronomy, enjoying the fantastic dark skies where I live in the Yorkshire Dales, but I thought it would be fun to see how a non-dedicated astrophotography rig with no tracking would perform. The image here was taken using a StellaLyra 8-inch Dobsonian and an iPhone 12 Pro, mounted over a standard Plössl eyepiece using the Celestron NexYZ phone adaptor. The iPhone camera app worked well, with only minor edits needed to bring out the contrast a little more. It whets the appetite for the slippery slope that is astrophotography!

I'm looking forward to more webinar presentations again this year – they have been great.

Andrew Downie, North Yorkshire

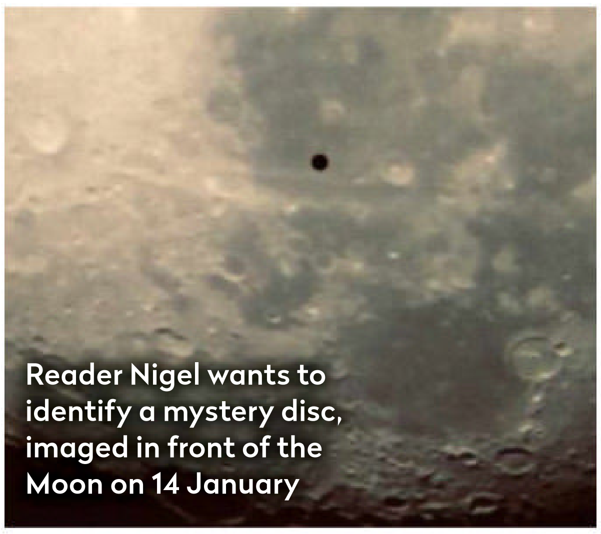


Andrew's first attempt at deep-sky imaging – the Orion Nebula

A good first deep-sky image effort, Andrew. We hope to see more as you progress down the slippery slope that is imaging! Do stay tuned for details of our next webinars – we'll have something for you very soon. ***– Ed.***

Tweet

Astro Mike
@xRMMike • Jan 17
Tonight's Wolf Moon (first full Moon of January), captured over Corsley, Wiltshire using a Celestron telescope with a focal length of 1,432mm. #WolfMoon #Lunar #Moon #MoonHour #astronomy @bbcweather @BBCSpringwatch @skyatnightmag



Reader Nigel wants to identify a mystery disc, imaged in front of the Moon on 14 January

Disc of mystery

Thank you for your excellent magazine, I look forward to it every month. Could anyone help in identifying an object that I managed to image (above) in my picture? It crossed the face of the Moon on Friday 14 January at 21:03 and appears as a small black disc. I was trying out a new drive system for my Celestron C102-HD refractor – the drive was a Christmas present from my wife. The image was taken on an iPhone 6 standard camera. My first thought was a weather balloon, but does anyone have any different ideas?

Nigel Williams, Clifford, Hereford

'Light' concerns

I really enjoyed the latest edition of *The Sky at Night* programme, which highlighted the issue of light pollution. It struck a real chord with me as I am sure it did with so many astronomers, professional and amateur, and others who have concerns about artificial lighting. I'm a member of the West Yorkshire Astronomical Society, Pontefract, and I have had a problem light shining into my back garden here in Crofton, near Wakefield, West Yorkshire since March 2020. The offending light is a repurposed


A streetlight is ruining Steve's view of the night sky

streetlight from the 1980s, which is activated by a day/night sensor and it's on during all hours of darkness. It is on a neighbouring building owned and operated by Wakefield and District Housing Association, and I have been calling on Wakefield District Council's Environmental Health Department to take action, so far without any luck. I have had my MP Jon Trickett write on my behalf and have sought advice where I can, emailing the Commission for Dark Skies as well as Citizens Advice, but so far none of my enquiries have resolved the problem.
Steve Kirkman, Crofton, West Yorkshire

Eclipse query

Having received my very first issue of your magazine (the January 2022 issue), I've started to go through it page by page. I had a question about something on page 19, in the 'Looking back' section. Talking about lunar eclipses, it says here, "In the outer portion of the shadow, known as the penumbra, Earth only partially shadows the Sun." Could you clarify that, or should it read 'Moon' where it says 'Sun'?
Bob Conway, via email

I hope you've enjoyed your first issue, Bob! In a lunar eclipse, Earth is the body doing the shadowing: our planet blocks light from the Sun reaching the Moon. So if you were on the Moon at the time, you would see Earth shadowing the Sun. From Earth we see this as the Moon turning red, as the light we see from the Moon has passed through our atmosphere. *– Ed.*

Constant issue

I have been told that the Hubble constant is not really ▸

ON FACEBOOK

WE ASKED: How can beginners become better astronomers?

Carol Miller I would suggest patience, online courses and books. Try not to learn too much about the night sky in one go. Having conversations with fellow amateur astronomers is the best way to pick up information. Above all, enjoy yourself!

Raymond Minty A pair of binoculars like 7x50s and *Norton's Star Atlas and Reference Handbook.*

Benedict Culm Don't rush, be patient. It takes time to build up the knowledge, experience and gear. Enjoy the peace and solitude of being under the stars; it's good for mind and body.

Emma Hugo Get outside and just look at a clear sky. Learn to navigate the constellations and recognise where they are in relation to each other. Get a good pair of binoculars or a small telescope and join a local astronomy club.

Brian Dwyer Spend 15–30 minutes every clear night recognising a few of the brightest stars in your sky. Keep track of their apparent motion during the nights and months ahead.

John Press Don't just buy a bargain telescope from eBay or Amazon. Instead, speak with your local astronomy club or a dedicated astronomy shop before parting with a penny.

SCOPE DOCTOR

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With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

What budget-friendly binoculars would you recommend to see star clusters and Saturn's rings from my home in Kathmandu, Nepal?

DONNA SHRESTHA


▲ A good pair of 10x50 binoculars are great value for money

Binoculars are an excellent way of observing many celestial objects, including star clusters, but the planets are very small and to observe Saturn's rings requires a magnification in excess of 20x. Even then the image will be extremely small and will show little detail; it will just be a sphere with 'ears'.

You can buy high magnification binoculars but these are expensive and require the additional cost of a substantial mounting. Perhaps a better approach would be to purchase a pair of binoculars for star clusters and general observing and a telescope for observing the planets, other smaller objects and the craters on the Moon.

The best value for money binoculars are 10x50 types with Porro-prisms as these will allow you to observe a huge range of objects, but buy the best pair you can afford.

A 6- to 8-inch Dobsonian telescope and a minimum magnification of 50x will allow you to observe Saturn's rings separated from the planet itself.

The purchase cost of these two instruments together would be much less than the cost of high magnification binoculars.

Steve's top tip

What is the difference between a 1.25-inch and 2-inch eyepiece?

The 1.25-inch and 2-inch measurement refers to the diameter of the eyepiece's barrel. Part of the construction of an eyepiece includes a metal or plastic ring within the barrel called a 'field stop', which limits the size of the observed field by appearing as a sharply defined circle in the view though a telescope. The maximum size of the field stop is dictated by the diameter of the barrel itself so to enjoy the widest view possible from a long focal length (low magnification) eyepiece, a 2-inch barrel can be used if your telescope can accommodate it, to increase the apparent field of view.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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BBC Sky at Night Magazine is published by Our Media Ltd (an Immediate Group Company) under licence from BBC Studios, which helps fund new BBC programmes.

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Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

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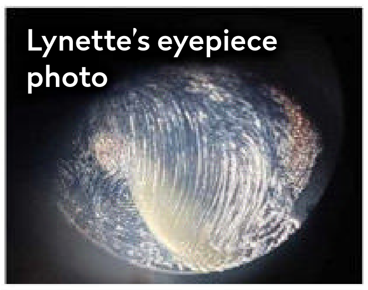
Audit Bureau of Circulations
20,788 (combined; Jan–Dec 2020)

ISSN 1745-9869

► constant, but changes over time. If this is the case, is our calculated value (whether 68 or 72) the true value of the Hubble constant at this moment in time, or is it from a previous point in time? If the latter is the case, when was it that the value was equal to our calculated value?
Ophelia Cornell, via email

Thanks for getting in touch, Ophelia. The Hubble parameter is what changes over time; we call its value in the current Universe the Hubble constant. ***– Ed***

Clarify the view

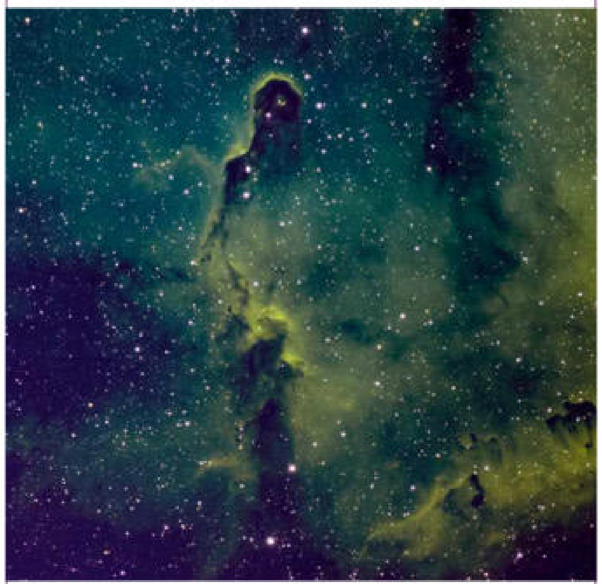


I have taken some pictures with my phone using my son's telescope, but I'm not sure what I have captured; I think it looks like a planet. Please could you let me know what you think it is?
Lynnette Holt, via email

Well done for getting the telescope out, Lynnette! What you've captured there looks to be a fingerprint on the eyepiece. It's easy to clean and there's a handy guide to doing it on our website at https://bit.ly/3IO8LHl . ***– Ed.***

Instagram

s_swift_2001 • 23 January



For today's quick data-processing, I've worked on an image of the Elephant's Trunk Nebula I captured from my Bortle 6 Nottingham back garden during some recent clear nights, though the bright Moon didn't help. It's a concentration of ionised interstellar gas and dust in Cepheus, about 2,400 lightyears away. #astrophotography #deepskyphotography #deepskyastrophotography @astrobackyard @bbcskyatnightmag

SOCIETY IN FOCUS

Many societies have become used to holding their meetings online since the start of the COVID pandemic and in November last year, the **Society for Popular Astronomy (SPA)** ran their annual weekend course via Zoom.

The course has been a familiar autumn fixture in the SPA's calendar since it was first held in 1977. Normally, members are welcomed to the field centre at Preston Montford, Shropshire, for observing and lectures, but in 2020 the event had to be cancelled. In 2021, however, the course was run over one day as a live online session for members.

Organised by SPA vice-president Robin Scagell, the course's theme was Observing the Planets. Talks were presented by regulars Robin Scagell and Professor Ian Morison, planetary scientist Dr Leigh Fletcher of the University of Leicester and imaging expert Martin Lewis.

Robin says: "Holding the meeting this way meant that many more members could get the feeling of being at the event. We had 77 participants from all over the country and more have now viewed the recordings.

"While it was an event that many members appreciated, we hope that next year we will be back in Shropshire and meeting each other in person once again."

Non-SPA members can catch up with the lectures, which cover the basics of planetary observing, in a series of videos at **tinyurl.com/SPAtalks**.

Paul Sutherland, Webmaster, SPA
► www.popastro.com

▲ **(Clockwise from top, left): Robin Scagell, Martin Lewis and Leigh Fletcher during an online session on planetary imaging**

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

PICK OF THE MONTH

▲ Enjoy a day of all things astronomy, with the latest gear, talks and demos – all with free entry

Live **Practical Astronomy Show 2022**

Kettering Conference Centre, Northamptonshire, 19 March

Whether it's choosing your first binoculars, upgrading your camera or even investing in your very own observatory dome, you will find all the movers and shakers in UK astronomy gear at the Practical Astronomy Show. Manufacturers, retailers and astronomy organisations will all be gathered under one roof at Kettering Conference Centre for a free day of displays and demonstrations, alongside expert talks from the likes of astrophotographer Damian Peach and *BBC Sky at Night Magazine*'s reviews editor Paul Money. Visit **practicalastroshow.com** to find out more.

Online **Exploring Space and Astronomy through Philately**

17 March, 7:30pm

Join the Astronomy Society of Glasgow via Zoom for this talk from Katrin Raynor-Evans (pictured, above) on how stamps from around the world have marked milestones in spaceflight and astronomy. See **www.theasg.org.uk** for login details.

Live **Observing at Rosse Observatory**

Carleton Road, Pontefract, 1 March, 7:30pm

All are welcome to drop in to West Yorkshire Astronomical Society's Rosse Observatory on the first Tuesday of each month. Entry is £6 per adult, with under-18s free. There's also a Young Astronomers' evening on the last Friday of each month, 6:30pm. £5 per child; booking essential at: **young.astronomers.wyas@gmail.com**.

Live **Public stargazing**

Low Dalby Astronomy Centre, Dalby Forest, North Yorkshire, 4 March, 8pm

Join Scarborough & Ryedale Astronomical Society to see the stars, planets, nebulae and galaxies under one of the darkest skies in the country. Book at **bit.ly/3qw2Ccu**

Online **The Planets of the Solar System**

Starts 15 March

This five-month course from the Astrophysics Research Institute will teach you everything about the interiors, surfaces and atmospheres of the planets and moons in our Solar System. The course costs £225. To book a place, visit **www.astronomy.ac.uk/info/planets**

Live & Online **Meteorites**

Bredhurst Village Hall, Gillingham, 25 March, 8pm

Meteorite specialist David Bryant explains how new meteorite discoveries have shaped our understanding of the origins of our Solar System; with a range of samples to handle. Non-members £3; contact **membersec@midkentastro.org.uk** (36 hours ahead) to join the talk.

Live & Online **Aliens in Science Fiction**

Gresham College, Holborn, London, 28 March, 6pm

From HG Wells to Octavia Butler's Xenogenesis series, the history of science professor Jim Endersby explores the portrayal of extraterrestrial lifeforms in science fiction. Book to see live or watch online: **www.gresham.ac.uk/lectures-and-events/scifi-aliens**

KATRIN RAYNOR-EVANS, NICK VERMEULEN X 4

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FIELD OF VIEW

Britain's best stargazing city?

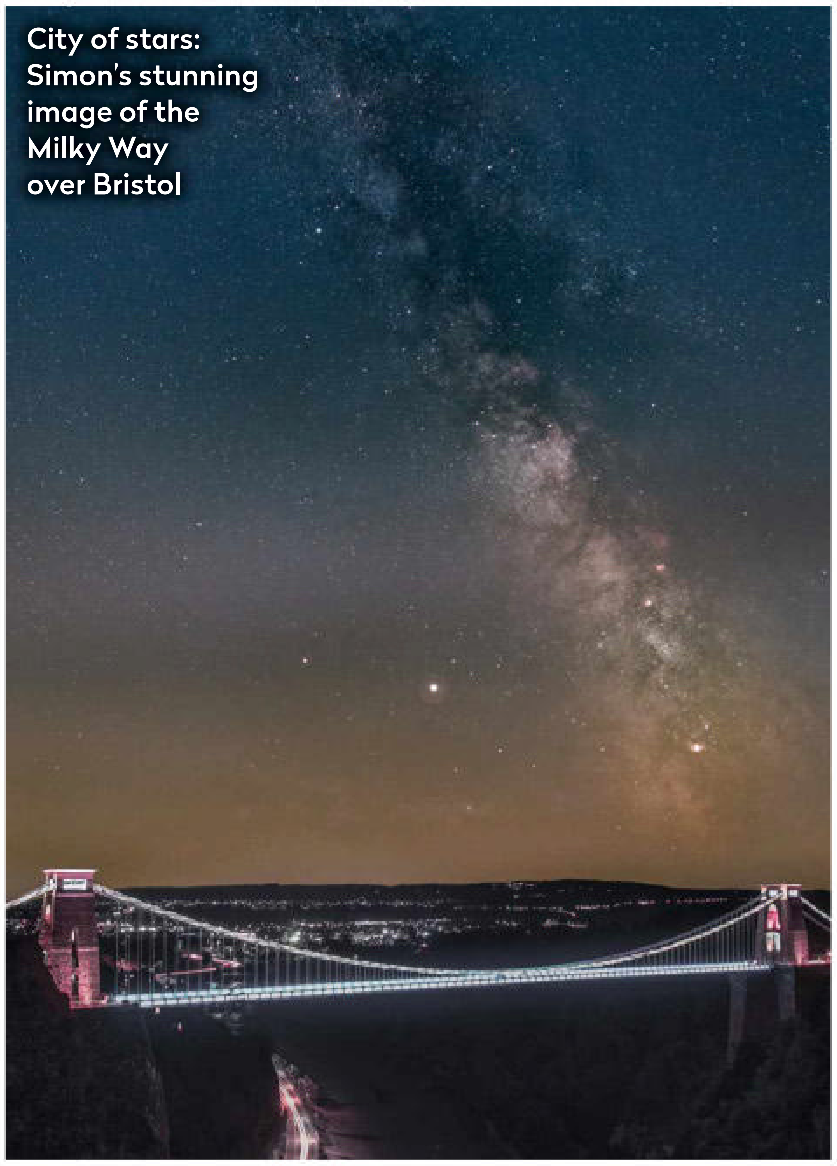
Astrophotographer **Simon Newman** describes imaging from Bristol, recently named the UK's best city for stargazing*, and shares some of his top tips

So how did I end up sitting for hours in the dark recently, on the cycle path under Bristol's iconic Clifton Suspension Bridge? As I sat there, I reminisced that I owe this astro-craziness to a broken hip. Back in 2018 I was recovering from a cycling accident with a lot of time to kill. Although I had a DSLR camera kit I never appreciated the hidden universe a camera could capture, be they the micro-details of insects or the macro-details of space. I started with insects, perfect for my confined recovery, and also started to absorb anything I could find online about photography, which led me to astrophotography – and that got me hooked!

I found myriad sub-genres and creative possibilities when photographing the night sky, many of which can be practised from the city. So, what type of astrophotography best lends itself to the light-polluted urban environment?

For starters there are astro landscapes; even in moderate light pollution, the asterisms and, of course, planets should be visible. I recommend that you choose recognisable ones and include these in your cityscapes. A glow filter can help accentuate these, allowing the most prominent stars to pop.

Star trails can work really well if you capture them from the slightly darker parts of a city, but it can be a challenge to balance the large dynamic range between the bright urban foreground and the dimmer stars. Either shoot with a low ISO setting to give yourself maximum dynamic range, or separately expose for the sky and the foreground, blending the two in post-processing. You can get creative and try a reflected star trail in a pond, window or mirror.



City of stars: Simon's stunning image of the Milky Way over Bristol

SIMON NEWMAN

Don't forget the Moon; a city's skyline features and landmarks present a perfect opportunity to get a striking composition with the Moon in shot, especially at a longer focal length. A shot planning app will help align these images. Even nicely framed by vegetation, or clouds, the Moon is one of my favourite subjects.

What about the deep sky? If you're shooting galaxies or nebulae, use good-quality filters. When I started out, capturing classics such as the Orion Nebula from my Bortle Class 6 Bristol garden, I bought an inexpensive light-pollution filter. It gave some improvement, but it was minimal. Then I invested in a couple of multi-band filters tailored to the specific narrowband wavelengths of the targets I was shooting, and these transformed my images. It's one of these filters that finally allowed me to capture the Milky Way above the Clifton Suspension Bridge.

Finally, I would also recommend that you try to image your targets when they're above the worst light dome of your urban environment to give the best contrast – even 10° can make a big difference.

Bristol is a great place for stargazing, but I also try to plan a couple of getaways to dark skies each year to shoot the Milky Way. I love the research, planning and anticipation which goes along with these mini adventures. From most cities, a trip of a couple of hours will get you to much darker skies. Bortle Class 4 skies or below give great results; my favourite locations are Dartmoor and the Brecon Beacons.

Simon Newman is a professional engineer and amateur photographer with a passion for astrophotography, who lives in Bristol with his young family

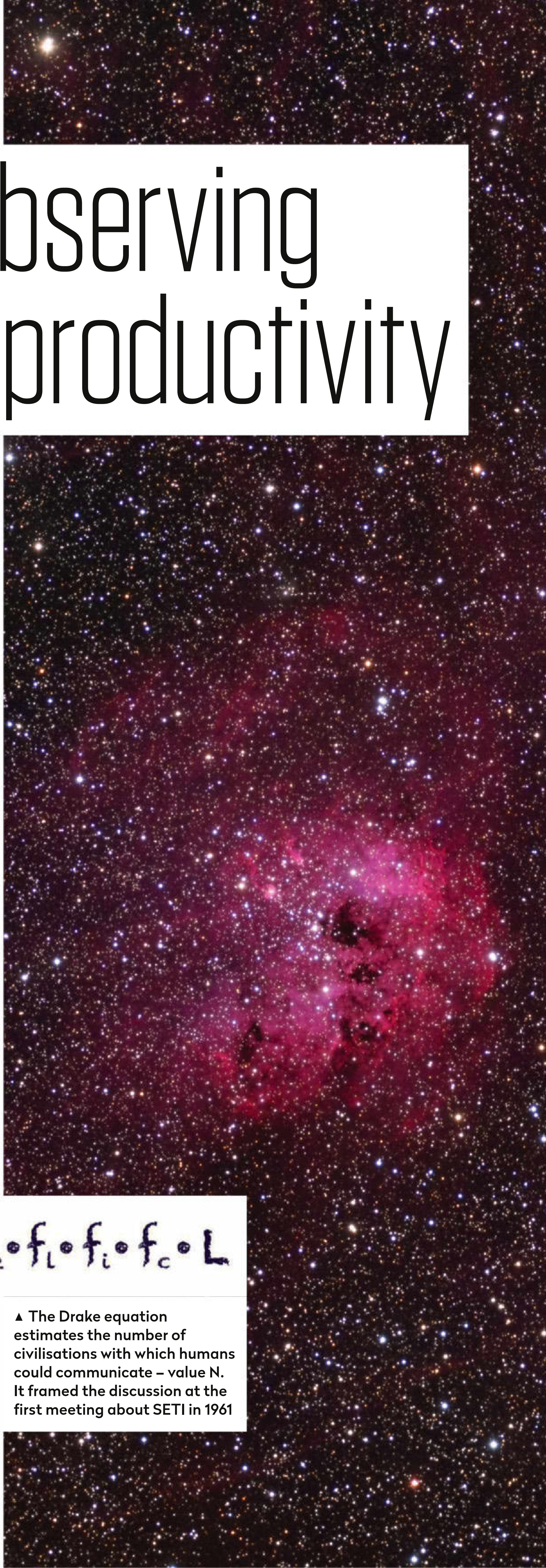
**Research released in November 2021 by McCarthy Stone. See bit.ly/MCSresearch for more*

Boost your observing and imaging productivity

By adapting the famous Drake equation, **Ron Brecher** shows us how we can spend more time enjoying the beauty of the night sky

The Drake Equation came about in 1961, when Dr Frank Drake formulated it to estimate the number of active and communicative civilisations that might be present in the Milky Way. The formula takes a probabilistic approach, multiplying different factors, such as the number of stars born every year, the fraction of stars that have planets, the length of time that a civilisation might survive, and so on. Drake's original motivation for crafting his famous equation was not to estimate the number of civilisations, but rather to frame the discussion during the first scientific meeting on the Search for Extraterrestrial Intelligence, or SETI. The SETI Institute provides lots more information about the Drake Equation at **www.seti.org/drake-equation-index**.

One feature of the Drake equation is that it can be adapted to address other big questions of great importance to readers of this magazine, such as 'How productive am I likely to be as an imager or observer of the night sky?' The answer to this simple question is surprisingly complicated. In fact, I've identified six factors that can affect an astronomer's productivity, which will all be discussed in this article. As you'll see, some are well within your control, while others are just a fact of life (*your* life), but their impacts on backyard astronomy can nevertheless be minimised. ▸



Frank Drake, here at Cornell University in 2017, is a pioneer of SETI – the Search for Extraterrestrial Intelligence

$$N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

▲ The Drake equation estimates the number of civilisations with which humans could communicate – value N. It framed the discussion at the first meeting about SETI in 1961

AMALEX5, SETI, RON BRECHER

When it all comes together, amateurs can witness the immense beauty of the night sky through the eyepiece or with a camera. IC 405 (upper right), IC 410 (lower left) and part of IC 417 (upper left) fill this view of Auriga, the Charioteer

◄ The author's Doghouse Observatory makes all-night imaging comfortable, even in the depths of winter. The walls also provide a wind break for the telescope, for steadier views

▼ Dress for a much colder temperature than it is, with a hat and gloves, and warm socks and boots. Also add a hot drink and some heating pads. An extra sock (lower left) over your finderscope can keep dew off

The Make-or-Break equation

► To begin to answer that question, 'How productive am I likely to be as an imager or observer of the night sky?', let's look at the 'Make-or-Break equation', adapted from the Drake equation. We can use this to estimate the number of productive nights per year for an amateur astronomer, denoted by N:

$$N = Y \times f_c \times f_m \times f_{fr} \times f_{bw} \times f_{bt} \times f_e$$

Where the various variables represent these factors:

- Y = total number of nights in a year
- f_c = fraction of nights that are clear
- f_m = fraction of nights that are more or less Moon-free
- f_{fr} = fraction of 'free' nights
- f_{bw} = fraction of nights with bearable wind
- f_{bt} = fraction of nights with a bearable temperature
- f_e = fraction of time that all equipment works properly

Let's look at understanding how these factors can influence productivity estimates and identify ways to mitigate factors that reduce productivity. I'll discuss both imaging and visual observing, as I enjoy both.

Managing the weather

The number of nights in a year (represented by the Y value of 365.25 nights) is an example of one factor that is beyond your control. Similarly, the Moon is up and interferes with deep-sky observing and imaging about half the time (f_m = 0.5), between first and last quarter, like it or not. Of course, visual observers, and planetary and lunar imagers are less bothered by moonlight – they may even relish it – so their f_m value is higher, perhaps 0.8. Imagers with narrowband filters can still image in moonlight, so a narrowband approach can increase overall productivity.

You only need to practise astronomy for a short time to conclude that you can't control the weather, and that is true: manipulating local cloud cover (f_c) is, of course, still beyond our grasp. However, other aspects of the weather – like intense cold, stifling heat and humidity – can be mitigated.

Visual observers and portable imagers are more affected by weather than those who use permanent setups, whether local or remote. The best way to increase the value of f_{bt} is to dress for the weather. On clear nights, our bodies radiate heat away into

RON BRECHER X 3, NGC 253 RAW DATA COURTESY OF BRETT SOAMES

The opportunities for remote observing and imaging are often more numerous. This image of the Silver Dollar Galaxy, NGC 253, was captured from a remote observatory in Australia and processed by the author

Astrophotographers who purchase time or host their equipment at a remote observatory can achieve the highest values for f_c. After all, it's always clear somewhere

space, so dress for a temperature that is about 10–15°C cooler than the thermometer says it is. Warm socks, boots, gloves and a hat will keep your extremities warm. On the coldest nights (about –28°C for me) I use disposable chemical heater packs in gloves and boots, and an extra heater in my pocket to defrost the eyepiece. It's also a good idea to have somewhere warm for battery-powered accessories like a flashlight or a laser pointer. Lastly, an insulated mug containing a piping-hot drink can help extend your observing or imaging session.

At the other extreme, summer nights can be warm and humid, and with them can come a plague of biting insects. I wear lightweight long-sleeved clothes and trousers, and spray my clothes with bug repellant, avoiding getting any on my hands or around my eyes – I have heard that they can damage optical coatings. If there's no breeze, a small fan can help keep you cool, too.

Wind is an important determining factor – not only for comfort, but also productivity, particularly when it comes to imaging. So how can we increase the value of f_{bw}? The more solidly mounted your telescope, the less you'll be affected by wind. An observing tent can help to mitigate the impact of any breezes on portable visual or photographic observing. Even better is a permanent setup with walls to block the wind; I've never had to interrupt an imaging session from my Doghouse Observatory because of wind.

Astrophotographers who purchase time or host their equipment at a remote observatory can achieve the highest values for f_c. After all, it's always clear somewhere. Commercial remote observatories are situated under some of the best skies in both hemispheres, including the southern United States, Chile, Spain and Australia. They're still affected by moonlight, of course, but you don't need to worry about temperature, wind or biting insects.

Planning pays off

Many of us come to astronomy in middle age or later. By this time in our lives, we usually have a lot of responsibilities, whether family, work or both. It can be hard to make time for astronomy. And it's not just acquiring imaging data that takes time, we also need time for other things, like planning an observing session, or processing raw data to make stunning photos. How can we maximise productivity for that little bit of free time (f_{fr}) when the stars align in a clear, moonless sky?

Portable gear needs to be set up and taken down for every imaging session. This process usually involves waiting until you can see enough stars to polar align, troubleshooting equipment issues along the way and then having to take down the gear when clouds roll in, only to start over again the next clear night. Anything you can do to increase the amount of ▸

◂ With cameras, filter wheels, focusers and a mount to control, it's important to ensure that drivers and software – and the computer they're installed on – are up to date and working reliably, and that equipment is set up properly. Try and make any checks before a session

▴ Even if you have top of the range equipment, a pair of binoculars can increase the productivity of your visual observing

▸ imaging vs setting up time is helpful here. Practise getting efficient and accurate at setting up your equipment so that you're ready to go at dusk. If you can safely leave all or part of your portable rig fully set up to use over multiple nights, that will reduce the set up and take down time. It will also make imaging or observing much more productive, assuming the weather cooperates. If you are using permanent setups for imaging or observing, these take almost no time to get up and running, provided conditions are good, and all the equipment is working.

When it comes to portability, the best solution for visual observers is a pair of binoculars. These require virtually no set up time and can hugely increase the number of evenings you can spend at least a few moments stargazing. Sometimes a few minutes of binocular therapy between broken clouds can help tide you over until the next clear, moonless night.

Hardware, software and drivers

Keeping the value of f_e near a value of 1 means that when conditions are right, your gear will work properly. The key to success is to do as much setting up, maintenance and testing as possible outside of prime imaging or observing time.

For visual observers, this means becoming efficient at setting up and taking down equipment. With a little practice, tasks like collimation or aligning your finder can be performed quickly, before it's dark enough for serious viewing. If you use a computerised, or Go-To, mount for observing, learn how it works during the day and practise using it on mediocre nights. That will make those prime sessions more rewarding, because you won't be fiddling with any kit.

Compared to visual observing setups, imaging setups contain a lot more components that have the potential to reduce the value of f_e. While I use an electronics-free 10- or 20-inch Dobsonian-mounted reflector – along with a red flashlight and a map – for most of my visual observing, my imaging rig is much more complicated. It includes a heavy-duty mount carrying two telescopes, each with a cooled camera, an electronic filter wheel and an electronic focuser. There's also a guide camera, a couple of dew heaters and a PC to control all the imaging equipment. Problems with the operation of any piece of equipment, such as its ability to connect to the computer (via its driver) or a software problem, can all end a night of imaging. And little things like cables hanging off your scope can cause big problems. Balance can change as the mount tracks, or worse, a cable can snag and cause damage to equipment.

Astrophotographers can practise the same good habits mentioned above for visual observers. Permanent setups should have their polar alignment checked periodically (mine changes slightly when the ground freezes or thaws). In addition, it is important to keep software and equipment drivers up to date. Note, however, that it is never necessary to do this right before a prime night of imaging, or during an expected stretch of good weather. Instead, do it when the forecast is poor if you can. I regularly back up my

Ron Brecher observes deep-sky objects from his driveway in Ontario, Canada, while simultaneously imaging from his observatory. See **astrodoc.ca**

RON BRECHER X 2, M-GUCCI/ISTOCK/GETTY IMAGES, WILL GATER

FACTOR	PORTABLE VISUAL	PORTABLE IMAGING	PERMANENT IMAGING	REMOTE IMAGING
Y	365	365	365	365
f_c	0.6	0.4	0.4	1.0
f_m	0.8	0.5	0.5	0.5
f_{fr}	0.5	0.5	0.8	0.9
f_{bw}	0.9	0.7	0.9	0.9
f_{bt}	0.7	0.7	0.9	1.0
f_e	0.9	0.8	0.9	1.0
N (night/year)	**50**	**14**	**43**	**148**

◂ In this table the author has applied the variables of the Make-or-Break equation to give examples of how many productive nights of astronomy per year might be achieved with different setups

PC so I can easily switch back to a setup that worked, if needed. An advantage of imaging remotely is that there's little you need to do to keep the value of f_e close to 1, as the observatory host is expected to keep all the equipment running smoothly.

If you use a computer for astronomy, you have probably experienced an unexpected shutdown. Operating system (OS) updates that automatically reboot the computer will stop an imaging run in its tracks. Fortunately, this is often easily solved by disabling automatic updates. If you can't disable these, you may be able to specify that they only occur during the day, when you aren't imaging. Applications (apps, programs) can crash, too. Again, testing during non-prime time will expose any problems, giving you a chance to fix them before your next session.

Visual observers usually don't need to worry about unplanned shutdowns due to electronics. But they can have other unplanned issues, such as dew on the optics. A dew shield and/or electric dew heaters are a must in dew-prone locations. I keep a sock over my red-dot finder to stop the front glass fogging up; without it, I can't find my visual targets.

▾ The Moon brightens the sky about half the time, making deep-sky objects harder to see. Embracing the Moon as a photographic or visual target can boost the number of nights you enjoy astronomy

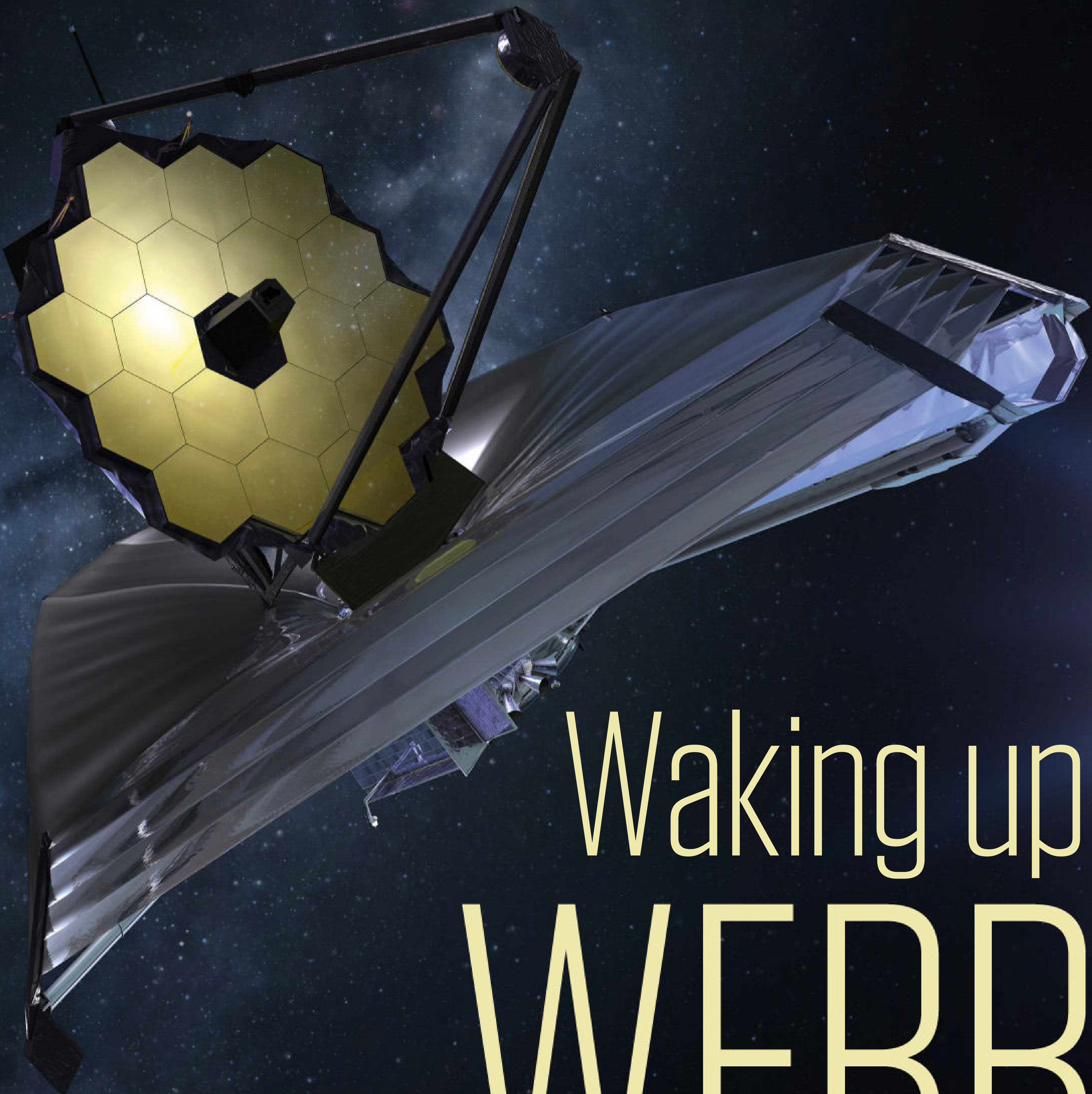
Productivity estimates

When you throw all of the factors discussed above into a pot and assign values for different scenarios, it's possible to estimate productivity, in nights per year. I've tabulated estimates for my own observing situations (see, table, left); your results may vary.

Eyepiece observers can expect four or five good viewing sessions a month, if they're not too bothered about moonlight. For astro imagers, there are big differences depending on your setup. Remote imaging can be done on any relatively Moon-free night, or about 148 nights per year. But, if like me, you enjoy hands-on time with your own equipment then a local permanent or portable setup may be a better, if less productive, choice. My productivity increased about threefold when I transitioned from a portable setup to a home observatory for imaging. I also observe with a portable setup, and sometimes access southern skies via remote observatories; truly the best of all worlds.

Enjoy the view

Viewed through the lens of the Make-or-Break equation, the obstacles amateur astronomers must surmount come into sharp focus. Fortunately, there are practical ways to adapt to our own unique circumstances and interests to maximise productivity. As in most things, success usually boils down to being well-prepared when opportunities present themselves and being able to recognise problems and implement solutions quickly. For me, the beauty of the sky, through the eyepiece and through the camera, makes it all worthwhile. To paraphrase the singer Miley Cyrus, astronomy's a climb, but the view is great. Enjoy the view as often as you can!



Waking up WEBB

The James Webb Space Telescope's launch and deployment was a storming success, but why haven't we seen the first pictures yet? **Govert Schilling** has the answer

The most powerful space telescope launched into space, JWST is a worthy successor to Hubble

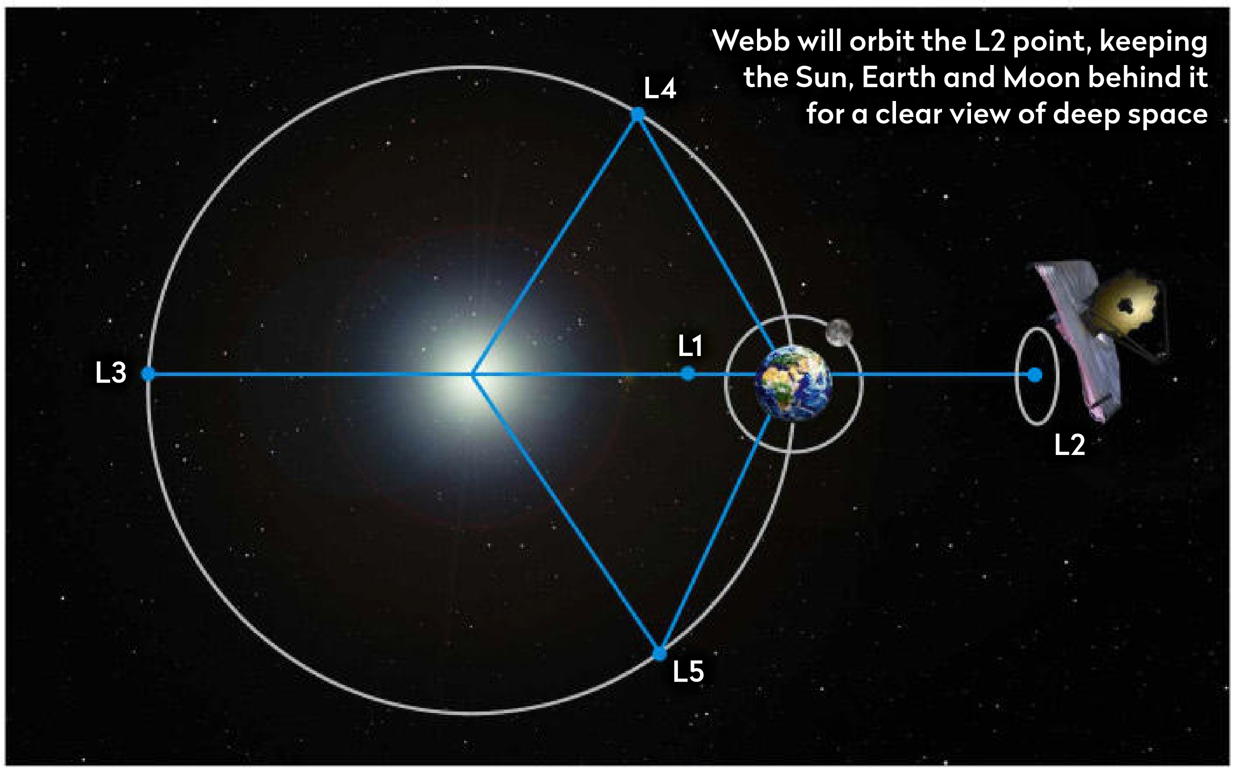
ILLUSTRATION

Captured by cameras on the upper stage of its Ariane 5 rocket, JWST sets off on its 1.5 million km voyage to L2 after separating on 25 December 2021

After 25 years and over 10 billion US dollars, on Christmas Day 2021, the James Webb Space Telescope (JWST) was finally launched into space by a European Ariane 5 rocket. With its 6.5-metre primary mirror and its tennis-court-sized sunshield, Webb had to be folded up to fit in the rocket's fairing, only to be deployed step by step in the first two weeks of its mission (see box, 'Unfolding the telescope', on p36). However, the successor to the Hubble Space Telescope won't take its first images of the Universe before late June or early July 2022, which begs the question – why?

It seems like an excessively long wait, especially since JWST arrived in its final orbit on 24 January. A total of three mid-course correction manoeuvres successfully placed the huge space telescope in a slow looping orbit around the second Lagrange point (L2), a stable gravitational point some 1.5 million kilometres behind Earth as seen from the Sun. "But a lot more needs to be done before we can start science operations," says Mark McCaughrean, the Senior Advisor for Science and Exploration at ESA (the European Space Agency), NASA's main partner in the programme.

For one, the telescope and its sensitive instruments, which left the French Guiana ▸



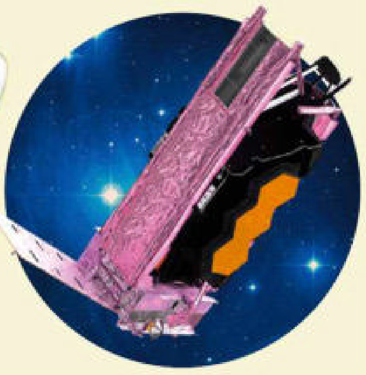
Webb will orbit the L2 point, keeping the Sun, Earth and Moon behind it for a clear view of deep space

DETLEV VAN RAVENSWAAY/SCIENCE PHOTO LIBRARY, ARIANESPACE/ESA/NASA/CSA/CNES

Unfolding a space telescope

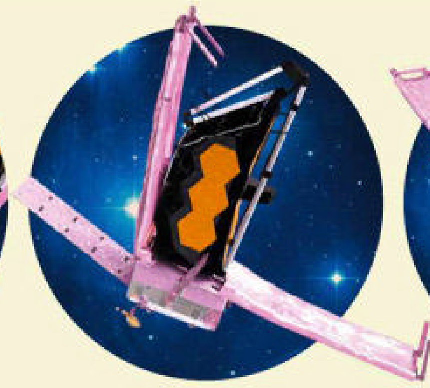
It took more than 50 individual steps and two weeks to set JWST up

25 December, 12:20 UT
JWST launches from the Guiana Space Centre on an Ariane 5 rocket; after 27 minutes, it separates from the launcher's upper stage to travel to L2 alone.



25 December, 12:48 UT
Deployment of JWST's 6m, five-panel solar array, which delivers about 1Kw of power. The telescope can now switch from battery power to its own power.

26 December
Deployment of the high-gain communications antenna, which allows communication with Earth through NASA's Deep Space Network.

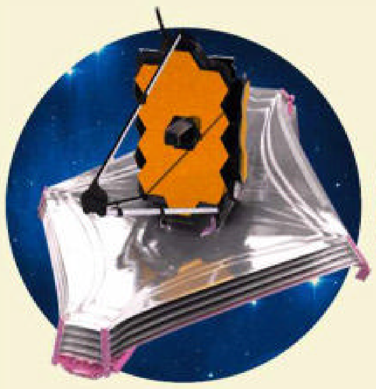


28 December
The Forward Unitized Pallet Structure (UPS), which supports and contains the five folded layers forming the front half of the sunshield, is lowered into place.

29 December
The Deployable Tower Assembly (DTA) is raised by 1.2m for better thermal isolation and to give room for the sunshield to unfold in front and behind.

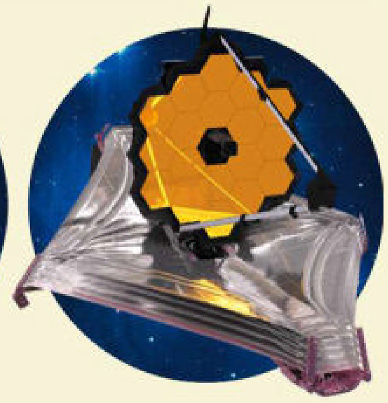
30–31 December
Sunshield mid-booms are extended on either side, pulling the folded sunshield layers with them, to form the first part of its distinctive 21m x 14m kite shape.

3–4 January
The five Kapton layers of Webb's sunshield are tensioned. While the Sun-facing side endures temperatures up to 90°C, the shielded side will be as cold as –230°C.



5 January
JWST's 74cm convex secondary mirror is deployed. The foldable structure supporting it has been dubbed "the world's most sophisticated tripod".

6 January
Deployment of the 1.2m x 2.4m Aft Deployable Instrument Radiator (ADIR), which radiates heat from the space telescope's science instruments into space.



7–8 January
Deployment of the two side panels forming JWST's 6.5m primary mirror. Its 18 hexagonal segments are made of lightweight beryllium coated with pure gold.

▸ launch platform at tropical temperatures, have to cool down to 230°C below zero. Thanks to its giant multi-layer sunshield, JWST had already reached –200 °C by early January, but the passive cooling slows down over time. It's a delicate process, says McCaughrean. For instance, the optics can never be the coldest parts of the telescope, lest molecules being released as gases from the graphite-composite support structure freeze down on the mirrors, degrading its performance.

When the NIRCam instrument (Near Infrared Camera) got cold enough for its sensitive mercury-cadmium-telluride detectors to pick up infrared light, the process of aligning the telescope's 18 mirror segments could finally commence. Each hexagonal segment is fitted with seven actuators and can be slightly tilted, shifted, rotated and deformed to ensure that they operate together as one perfect parabolic surface. And since the alignment procedure is done with starlight, it marks JWST's 'first light'. But it will take months of incremental precision adjustments before the 18 individual stellar images from each mirror are all brought together into one single focus.

Instrument testing

Around late April, engineers will also start commissioning JWST's four large science instruments: NIRCam (Near InfraRed Camera), NIRSpec (Near InfraRed Spectrometer), MIRI (Mid InfraRed Instrument (see box, opposite), and the Canadian FGS/NIRISS (Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph). Equipped with beam splitters, filters and micro-shutters, all have different observing modes, and these have to be fully tested and calibrated before they are handed over to the astronomy community. "Of course, every instrument has been tested and checked on Earth," says McCaughrean, "But we need to prove that they also perform flawlessly in space."

So what about that supposedly awe-inspiring first picture taken by the new space telescope? Well, that's not expected until some six months after launch, which would be late June or early July. And according to McCaughrean, "What it will show is a closely guarded secret. Most likely some kind of star-forming region."

"Astronomers can't wait to train their new, expensive toy on their favourite objects"

ILLUSTRATION

With more fuel left over after its precision Ariane 5 rocket launch, JWST can stay in orbit at L2 for much longer than anticipated

Then again, he imagines that NASA may eventually decide to release an earlier test or alignment image at some time. "The longer it takes, the more people will start to believe something must be broken. There may even be political pressure on NASA to put something out at an earlier stage – they'd better prepare for this."

Anyway, the first round of science observations won't start before summer. Astronomers can't wait to train their new, expensive toy on their favourite objects, be that a remote galaxy at the dawn of time, a planet-spawning circumstellar disc, an exoplanet's atmosphere, or a denizen of our own outer Solar System.

Field of regard

Webb has less pointing flexibility than Hubble: since the telescope must face away from the Sun to keep its instruments consistently cool, its 'field of regard' will cover 40 per cent of the sky on any given day, and it will take around six months to access the whole of the sky.

The good news is that JWST's mid-course corrections used up less fuel than expected, which means there's more left to keep the space telescope in its L2 orbit. As a result, its operational lifetime may be extended beyond the projected operational period of 10 years. In any case, the exciting results Webb is bound to deliver will make up for the half-year wait we're experiencing right now.

Govert Schilling is an astronomy journalist and broadcaster, and author of *Ripples in Spacetime*

Europe's place on Webb

Led by the UK, European partners built one of JWST's main instruments

MIRI (Mid Infrared Instrument) is the major European contribution to Webb, apart from the Ariane launch. A camera and spectrometer combined, it was designed and built by a 10-country European consortium led by the UK, in collaboration with NASA.

MIRI's high spectral resolution enables it to identify a huge range of molecules in star-forming regions, protoplanetary discs and exoplanet atmospheres. The instrument's principal investigator is Professor Gillian Wright of the UK Astronomy Technology Centre, Edinburgh.

"MIRI's capabilities cannot be achieved by ground-based telescopes," she says. "The Earth's atmosphere is too efficient at blocking mid-infrared wavelengths. Uncooled telescopes on Earth also emit their own mid-infrared light; for them to do MIRI's work would be like looking for a match with a telescope that's on fire. Webb is cold and far beyond Earth's atmosphere, making MIRI hundreds of times more sensitive than any other instrument like it."

To be this sensitive, MIRI has to be cooled to 6.7°C above absolute zero, or –266.5°C. Since JWST's sunshield will only provide temperatures as low as –230°C, the instrument also has a cryo-cooler, which acts like a refrigerator. A set of four coronagraphs enables the study of extrasolar planets without being 'blinded' by the radiation of the planets' host stars.

MIRI (left) being integrated into JWST's science payload module at NASA's Goddard Space Flight Center in 2013

MIRI was Webb's first instrument to be completed and was integrated with the JWST in the US in 2013, after a final round of tests at the Rutherford Appleton Laboratory in Oxfordshire.

EXPLAINER

What's behind the UK's big aurora displays?

Melanie Windridge looks at the influence of recent increases in solar activity

This aurora season has proved a good one so far, particularly for aurora-watchers in the UK, with numerous newspaper reports of Northern Lights seen in the UK since September. This is likely due to an uptick in solar activity as part of the solar cycle, but before we go into that, let's think about what causes the aurora in general.

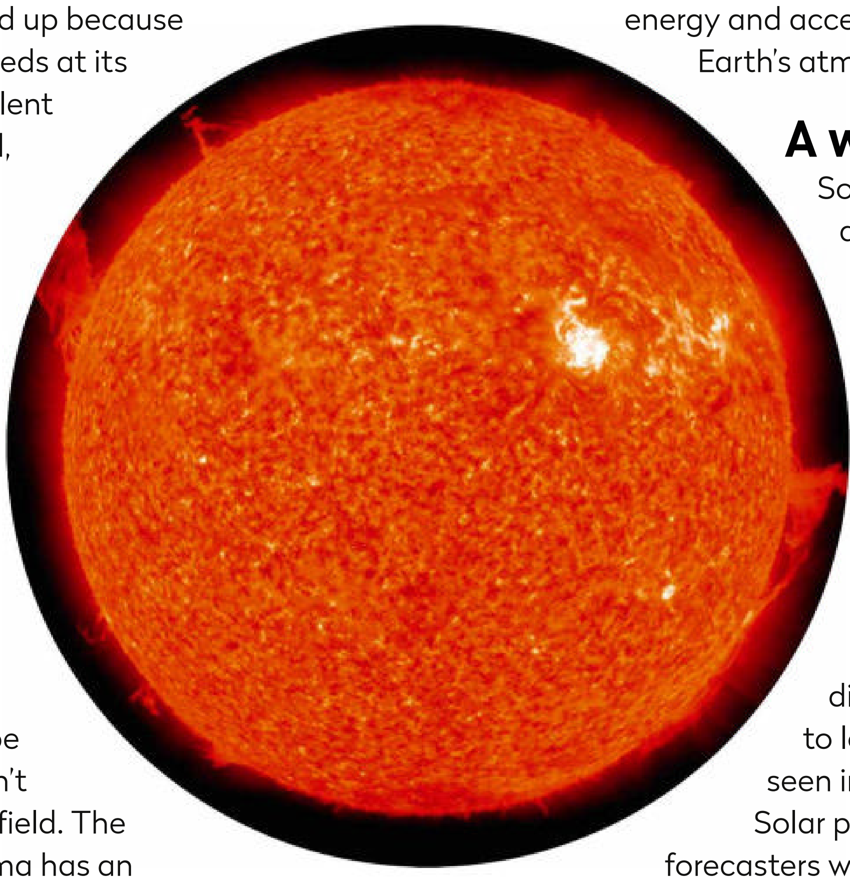
The aurora is an incredible light show caused by charged particles accelerated into our upper atmosphere. This acceleration process is driven by the Sun, so the changing power – or activity – of the Sun affects the aurora we see.

When we are young we often think of the Sun as a uniform yellow ball in the sky, but look closely at NASA pictures and you'll see that the Sun's surface is anything but uniform. The Sun is made of plasma, an electrically charged gas of mostly hydrogen and helium. The surface is a bit like a boiling pan of water, with hot material welling up and cooler material dropping down. This motion is stirred up because the Sun also rotates at different speeds at its poles and equator, making for turbulent flows. Magnetic fields are generated, and are twisted into loops emerging from the surface by this rotation.

Some of the Sun's plasma is also released into space – the Sun's atmosphere expanding out in all directions. This is called the solar wind, and it is this that drives the aurora on Earth. In addition to the ordinary outflow of particles, the Sun also throws off extra particles when twisted magnetic loops break and fling out solar matter.

All the charged particles flowing towards us in the solar wind would be dangerous for life on Earth if we didn't have protection from our magnetic field. The electrically charged solar wind plasma has an embedded magnetic field, and magnetic fields can't cross each other, so when the solar wind hits Earth's magnetic field it is deflected around us. As it does so, it interacts with our magnetic field, transferring energy and accelerating charged particles into Earth's atmosphere to cause the aurora.

When the solar wind is more intense, the 'auroral oval' of activity stretches down from higher latitudes to include the UK, like this County Durham display on 17 September 2021



▲ A NASA image of the Sun shows the turbulent activity that fuels solar wind

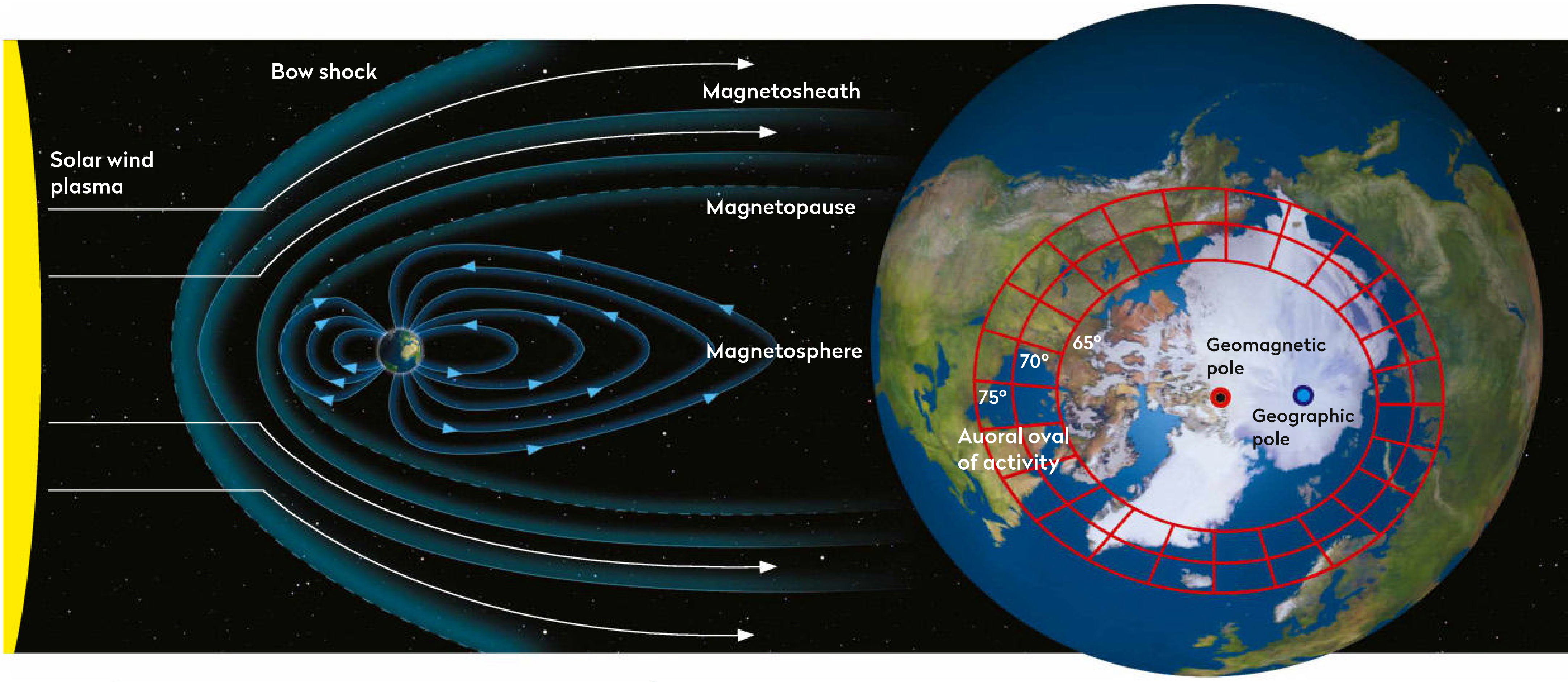
A wider region of activity

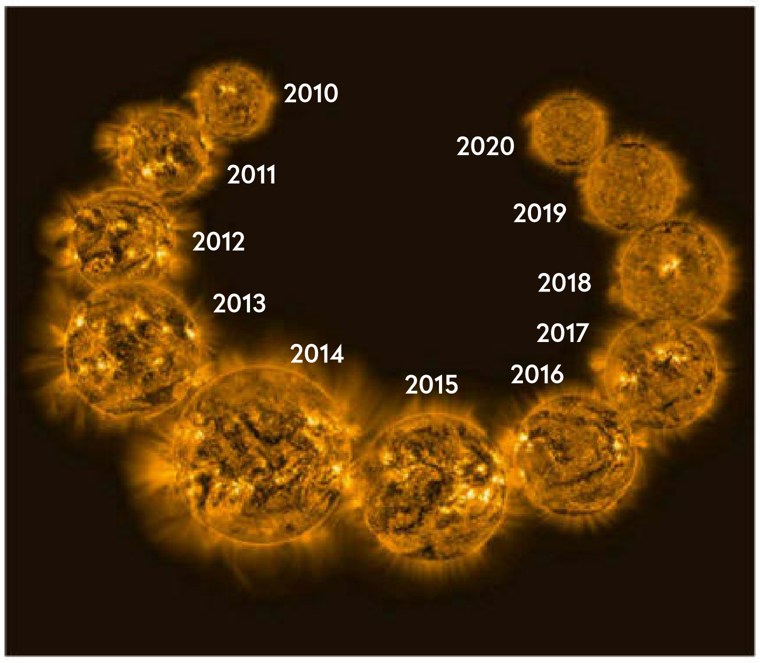
So, why do we sometimes see more aurora displays in the UK than at other times?

The aurora happens in rings around Earth's poles, most often seen between about 65° and 75° latitude. This is the region where aurorae will be generated by just everyday solar wind. But sometimes solar wind conditions are stronger, faster and denser, and this can cause bigger aurora displays that expand the auroral oval to lower latitudes, where they may be seen in the UK or even further south.

Solar physicists or space weather forecasters will talk about the 'activity' of the Sun. This can be measured by things like sunspots on its surface – the more sunspots, the more twisted the magnetic field. It is these dark, active regions where the twisted field lines can break and throw extra

DAVID FORSTER/ALAMY STOCK PHOTO, NASA/SDO, ILLUSTRATIONS BY PAUL WOOTTON, DAN SEATON/ESA/ NOAA/JPL-CALTECH, OLIVER TAYLOR/ALAMY STOCK PHOTO





▲ As it nears solar maximum (as seen here in Solar Cycle 24), the Sun's activity increases dramatically

▲ **Aurora displays are caused when charged particles, streaming out of the Sun interact with Earth's magnetic field**

Dr Melanie Windridge is a plasma physicist, speaker, author of *Aurora: In Search of the Northern Lights* and the founder of Aurora Stories

matter out into the solar wind; really big examples are called coronal mass ejections (CMEs). These events are the ones that cause the biggest 'solar storms' and the brightest aurora. Light from these stretches up by hundreds of metres in Earth's atmosphere.

The Sun's activity waxes and wanes over an 11-year cycle. 'Solar maximum' is when the number of sunspots visible on the disc of the Sun is at its peak; it is when the solar magnetic field is most disrupted and there's an increased likelihood of solar flares and coronal mass ejections. At solar maximum, the polarity of the Sun's magnetic field flips completely and then gradually relaxes back to a minimum, undisrupted state before twisting itself up all over again.

The last solar minimum ended in October 2020 so solar activity is now ramping up – we are now in Solar Cycle 25 – with the next peak predicted to be around mid-2025. That means we should see an increase in the frequency of space weather storms, and therefore UK aurora displays, over the coming years.

▸ **Turn the page to see the different types of aurora that can form, shown on a photo taken during a recent aurora display.**

Chasing the Northern Lights in the UK

Now is the time to search for one of nature's most spectacular sights

To see the Northern Lights anywhere you need a spot looking north with a clear horizon, where there is minimal light pollution. In more populated latitudes, a good location is somewhere like a northern coastline, looking out across the sea.

In general, the best places in the UK to see the aurora are the places furthest north. So, of course, Scotland is ideal, and there are some beautiful photographs of displays taken from Caithness (pictured, right), the Moray coast, Aberdeenshire, Shetland and the Western Isles.

However, for more active aurora displays where the auroral oval spreads further south, many people have luck seeing the aurora in coastal areas of Northern England such as Bamburgh or Whitley Bay in Northumberland (both known for their dark skies); north Norfolk; Northern Ireland; and even Pembrokeshire in Wales, which is barely further north than Oxford. In the UK, light pollution and clouds have the biggest impact on the visibility of mid-latitude auroral displays.

▲ A stunning aurora display captured over Caithness, appearing over the Noss Head Lighthouse on 27 January 2017

CURTAINS

A common form of rayed band, a curtain stretches high vertically and contains kinks or folds. The usual aurora colour is green, but if the display is very 'active' you may see red at the top edge of curtains, with pinks, purples and yellows lower down.

RAYS

Rays look like pillars of light stretching upwards, or as striations in the arc or band. The structure is due to charged particles travelling down magnetic field lines, and colours depend on the composition of the atmosphere and the energy of the incoming particles.

RAYED BAND

If a band or arc contains rays, then it is known as a rayed band or rayed arc.

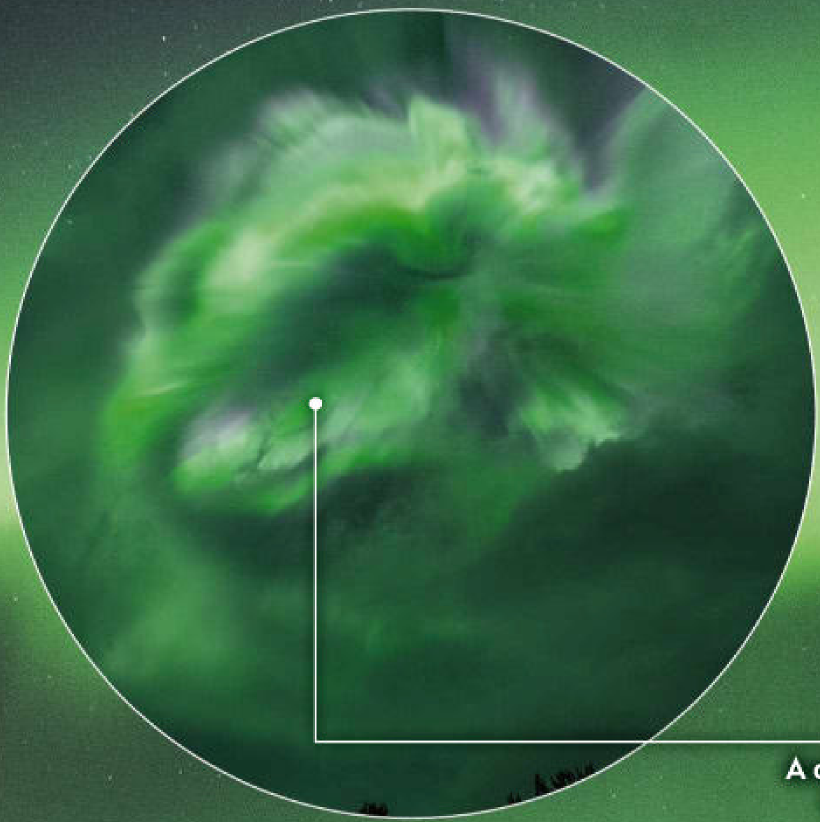
BANDS

A band is a form of arc, but with an irregular, wavy lower border rather than a smooth one; they can stretch thousands of kilometres across the sky.

Get to know the SHAPES OF THE AURORA

Learn the forms of the natural world's most stunning light show

There has recently been an uplift in dramatic aurora displays, which ties in with increased activity in the Sun's latest solar cycle (see page 38). These beautiful photos, taken in Finland and Norway by Markus Varick in late 2021, are awash with aurora forms. Here, plasma scientist Dr Melanie Windridge explains the main forms to look out for in a display.



ARCS

An auroral arc is a simple curve of light across the sky with a smooth, well-defined lower border. Displays often start as an arc and they can stretch thousands of kilometres horizontally.

CORONA

A corona consists of multiple twisted, rayed bands seen directly overhead, so they appear to converge to a zenith. The formation is named after a crown and looks like a large starburst.

VEILS

If the aurora is very 'quiet' you may see the aurora as a veil – a diffuse, pale light that covers a wide area of sky, which has no obvious structure and is usually very faint.

PATCHES

Patches are regions of diffuse, less concentrated glow that appear in blobs and may pulse in brightness.

Capturing the aurora

Photographer **Markus Varik** explains how he shot his two images

"The idea for the main picture came about in the early hours of 12 October 2021, when a G2 (moderate) geomagnetic storm reached Earth. The evening weather forecast was promising, so we headed to Finland and drove for three hours. We found these astonishing clear skies on the coast and didn't have to wait long – the aurora was pure magic.

"The inset image was taken above Tromsø, Norway, on 3 November. It had been raining for hours, and the next moment there were clear skies – we had the best aurora crown we've seen for years!"

Equipment: Canon 5D DSLR cameras, Sigma 20mm f/1.4 and 14mm f/1.8 lenses

Markus Varik is an aurora photographer and tour guide based in Tromsø, Norway. For more details see **https://greenlander.no** and **www.instagram.com/greenlander_tromso**

ALL PICTURES: MARKUS VARIK/HTTPS://GREENLANDER.NO/ WWW.INSTAGRAM.COM/GREENLANDER_TROMSO, WWW.FACEBOOK.COM/GREENLANDERTROMSO

16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

MARCH 2022

PLEIADES AND THE MOON

View a beautiful waxing crescent Moon near the Seven Sisters on 8 March

MORNING MEETING

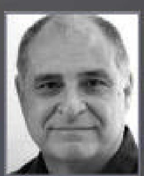
Venus, Jupiter and Mars are joined by a waning crescent

THE JEWELLED HANDLE

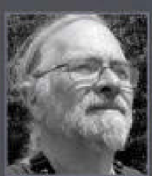
See the Jura mountains' peaks lit by lunar dawn

PETE LAWRENCE

About the writers



Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month…

- ✦ Comet19P/Borrelly near the Pleiades
- ✦ A last chance to catch Orion in the evening sky
- ✦ Get to know the lunar feature Rupes Recta

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

MARCH HIGHLIGHTS
Your guide to the night sky this month

Tuesday

1 Comet 19P/Borrelly remains relatively bright this month and is well placed, passing from Aries, the Ram into the southern part of Perseus, the Hero. Turn to page 47 to find out how to locate it.

Wednesday

2 Mag. 0.0 Mercury and mag. +0.9 Saturn are just 50 arcminutes apart as they rise 30 minutes before the Sun today. Be warned though, as this will be a tricky observation at best!

Thursday

3 Minor planet 16 Psyche reaches opposition at mag. +10.4. Psyche can be located under the belly of Leo, the Lion.

Friday

4 The Moon is re-emerging into the evening sky, but still sets early enough to try our 'Deep-Sky Tour' on page 56. This month we're looking at objects around Melotte 111 in the small constellation of Coma Berenices, Berenice's Hair.

◀ Tuesday

8 This evening's 35%-lit waxing crescent Moon lies 4.1° south of the Pleiades open cluster.

Thursday ▶

10 Venus sits 4.1° north of mag. Mars, low above the southeast horizon, visible 1 hour before sunrise.

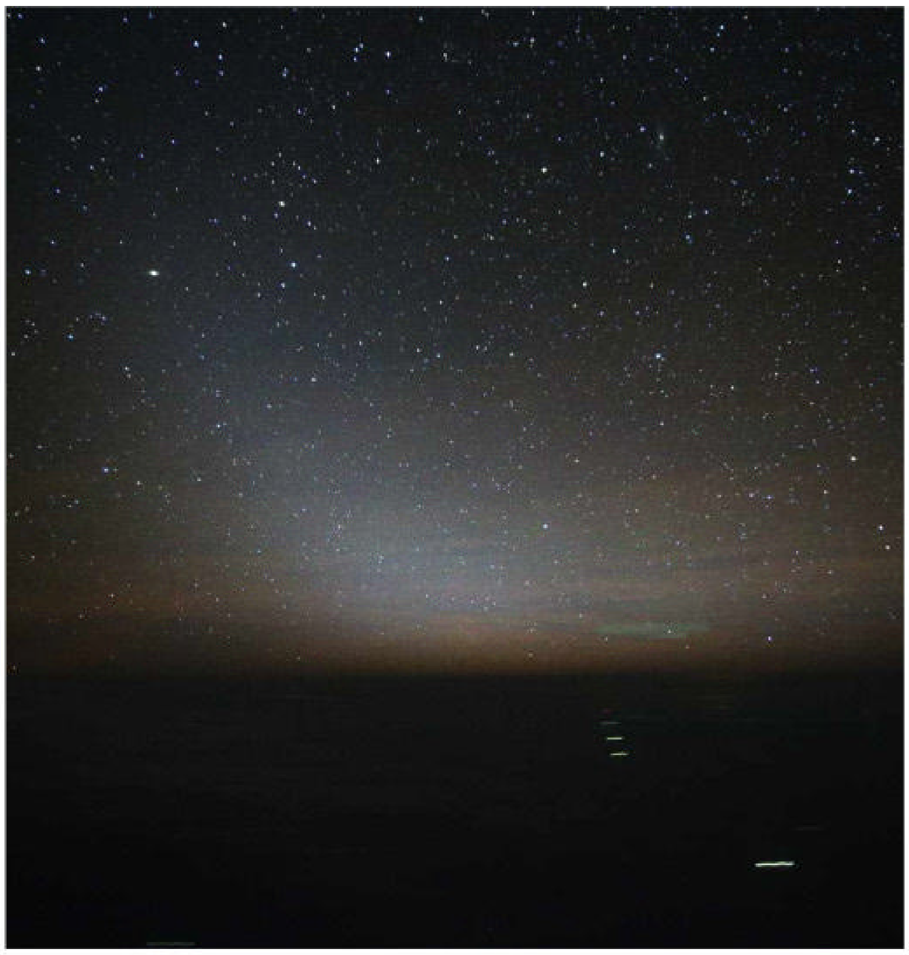
The clair-obscur effect within crater Ptolemaeus, known as Nessie, can be seen around 17:29 UT.

Saturday ▶

12 The clair-obscur effect known as the Jewelled Handle can be seen this evening. This occurs when the light from the lunar dawn illuminates the peaks in the semi-circular Jura mountain range.

Tuesday

15 Minor planet 39 Laetitia reaches opposition today. Predicted to reach mag. +10.3, Laetitia can be found among the stars of Virgo, the Virgin passing northwest out of the Bowl asterism.



◀ Wednesday

23 If you have dark skies and clear weather after sunset, look out for the extremely faint glow of the Zodiacal light in the west. The inclined cone of light, caused by dust in the Solar System scattering sunlight, runs along the length of the ecliptic.

Thursday

24 A low triangular formation is visible between mag. +0.9 Saturn, mag. –4.2 Venus and mag. +1.1 Mars. Catch this impressive trio an hour before sunrise, rising above the east-southeast horizon.

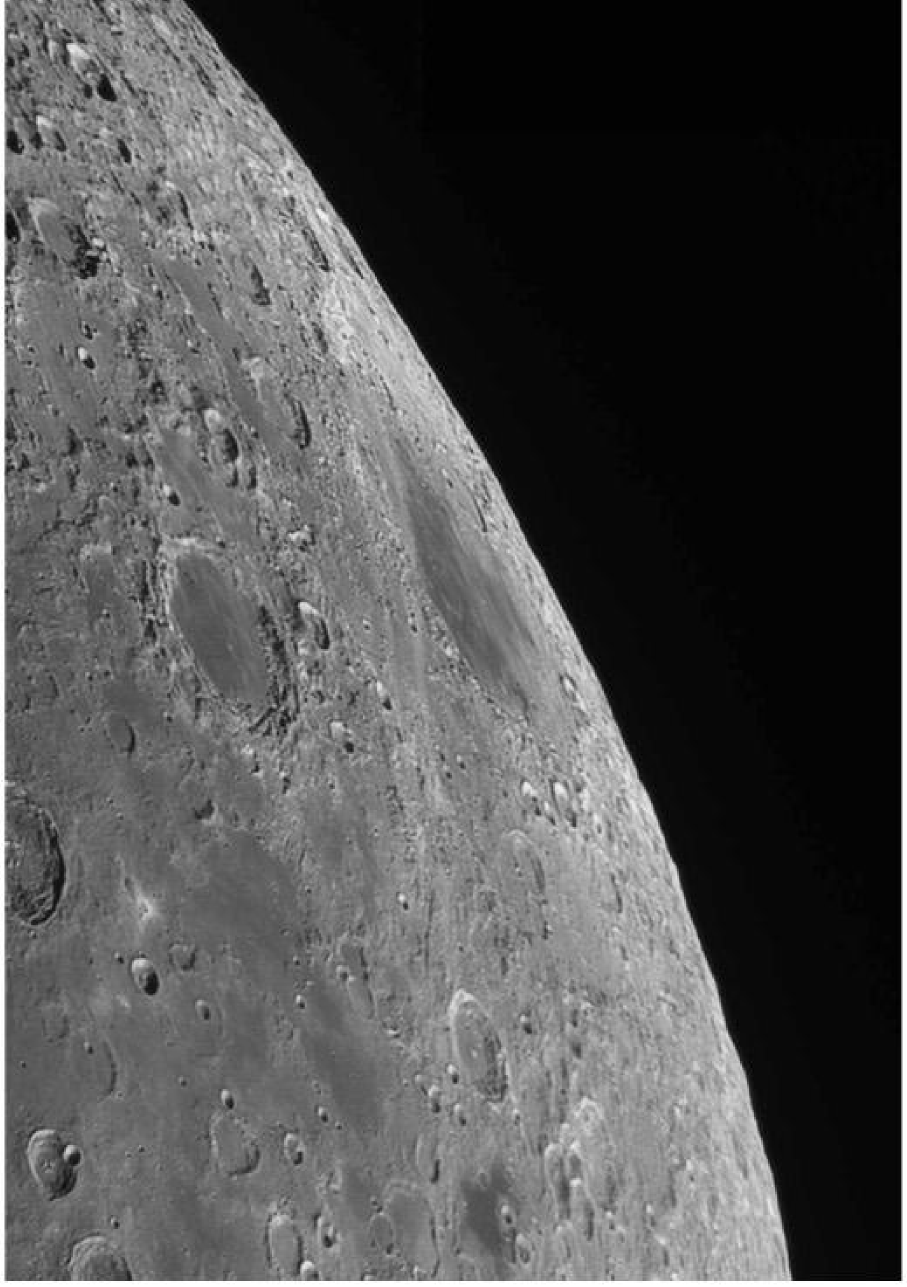
Monday

28 Venus, Mars and Saturn are joined by an 18%-lit waning crescent Moon. The quartet can be seen rising above the southeast horizon approximately 40 minutes before sunrise.

Tuesday

29 Mag. –4.2 Venus sits 2.1° to the north of mag. +0.9 Saturn this morning with mag. +1.1 Mars 4.5° to the west of Saturn. Catch them approximately 40 minutes before sunrise, rising above the southeast horizon.

PETE LAWRENCE X 7



Saturday ▶

5 Catch the early evening 10%-lit waxing crescent Moon and see three libration-locked seas: Mare Humboldtianum in the north, and Mare Symthii and Mare Marginis to the east. The Moon's rocking and rolling libration state is favourable for viewing these.

Saturday

19 This morning the just past full Moon occults the binary star Porrima (Gamma (γ) Virginis) as the dawn is breaking. Disappearance occurs at 05:52 UT from the centre of the UK.

◀ Sunday

20 Venus reaches greatest western elongation, a beautiful morning sky beacon.

At 15:33 UT the centre of the Sun's disc crosses the celestial equator marking the Northern Hemisphere's spring equinox.

◀ Friday

25 As the nights shrink in length at this time of year, Orion's drift to the west means the Hunter's days are numbered. With the Moon out of the way, look at the Orion Nebula before it's consigned to the morning sky once more.

Sunday

27 In the UK, the clocks advance one hour at 01:00 UT this morning to become 02:00 BST, which marks the start of British Summer Time.

Wednesday

30 Although there are a few Messier objects not currently visible, it's possible, given clear skies to view most of the catalogue over the course of a full night currently. Why not give it a try and see how many you can catch?

Family stargazing

The Plough, or Saucepan, is a familiar pattern visible whenever it is clear and dark in the UK. It sits more or less overhead early evening during March. See if your young astronomers can pick it out and ask them to draw its shape. Point out the pan and the handle and explain that extending the side of the pan furthest from the handle up with respect to the Saucepan points at the North Star, Polaris. Drop a vertical from Polaris and where it meets the horizon is due north. Explain that the two pan stars that are used are called the 'Pointers' for this reason. **bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly Objects marked with this icon are perfect for showing to children

Naked eye Allow 20 minutes for your eyes to become dark-adapted

Photo opp Use a CCD, planetary camera or standard DSLR

Binoculars 10x50 recommended

Small/ medium scope Reflector/SCT under 6 inches, refractor under 4 inches

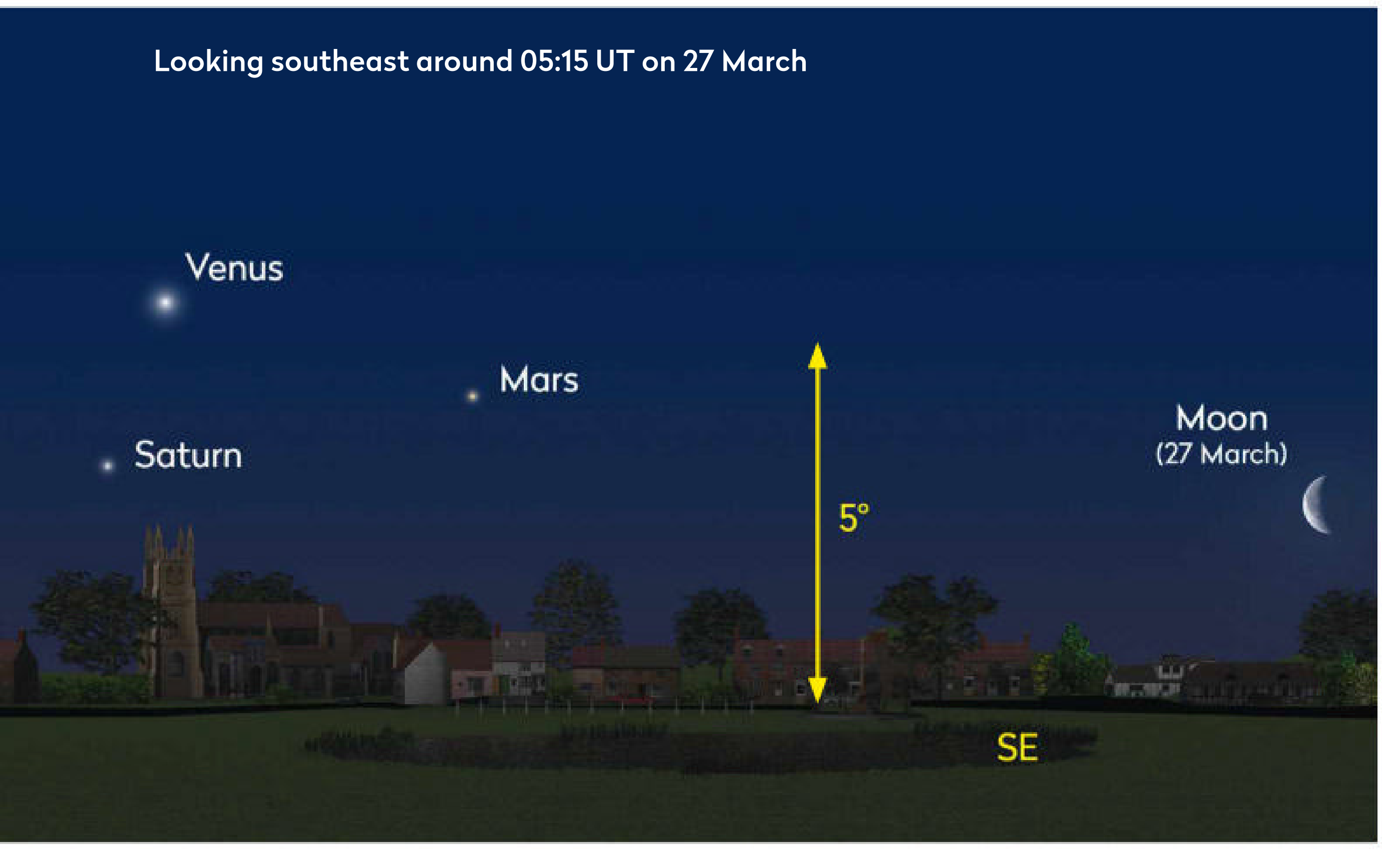
Large scope Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

DON'T MISS

Venus, Saturn and Mars join the Moon for a morning meeting

BEST TIME TO SEE: All month



▲ A waning crescent Moon joins the trio of morning planets towards the month's end

The morning sky is getting interesting this month as a trio of planets jostle for position. The group consists of Venus, Mars and Saturn, which all appear rather low when they are observed from the UK. Dimmer Mars and Saturn take advantage of the fact that they appear close to the bright planet Venus which, currently shining at mag. −4.4, is considerably easier to see despite its low pre-sunrise altitude.

At the start of March, Mars rises approximately 90 minutes before the Sun, popping up above the southeast horizon while 5° south of Venus. Mars will be shining at mag. +1.3 on this date, and easy to recognise because of its orange hue.

On 8 March, the gap will have closed between Venus and Mars, the separation being 4.3° on this date. Mars will be a fraction brighter too, at mag. +1.2.

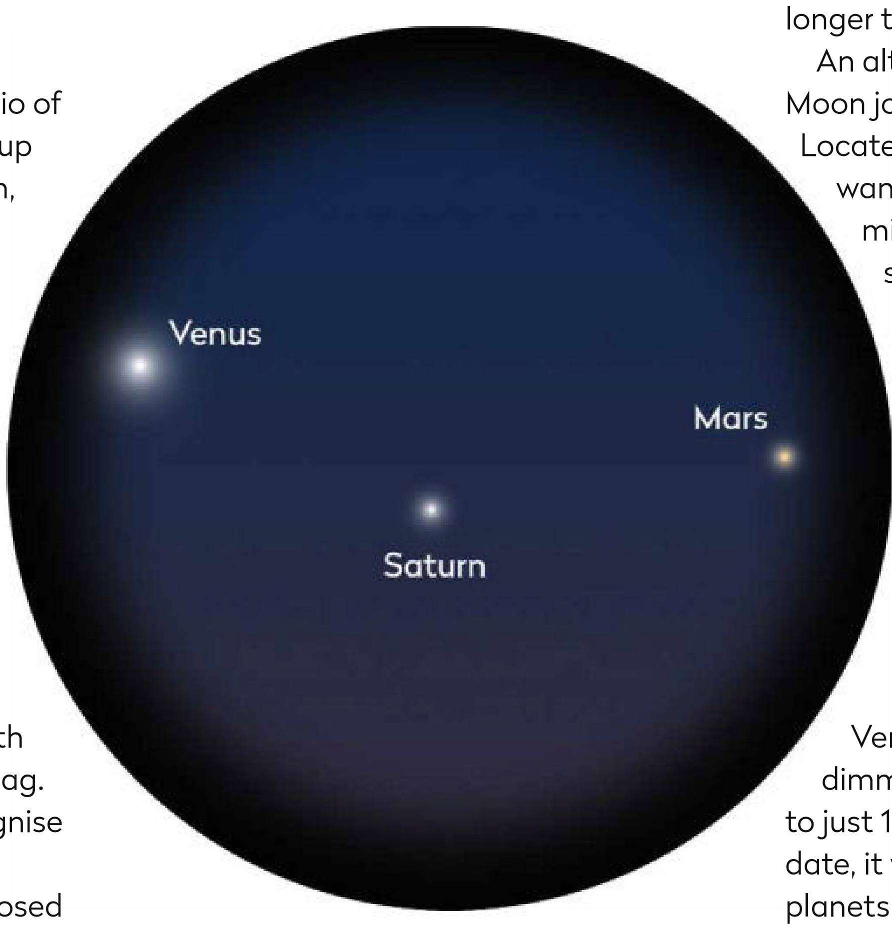
By 13 March, the gap will have dropped to a fraction less than 4°. It's about this time that mag. +0.9 Saturn may be glimpsed, rising 30 minutes after Mars. Venus remains close to Mars over the next few mornings, only starting to separate from the Red Planet around 18 March. Mars, Venus and Saturn will be contained within a circle 12° across on this date.

By 23 March, the containing circle will have reduced in size to 8.5°, the three planets now quite tightly packed together. It's fascinating to watch the pattern formed by the trio change shape over the remainder of the month. On the morning of 24 March, they form a squat isosceles triangle, with Venus as the upper vertex. Mars will have brightened to mag. +1.1 on this date. All three planets are above the horizon 60 minutes before the Sun, but will need at least 20 minutes longer to reach a visible altitude.

An altitude-challenged waning crescent Moon joins the group on 28 March. Located 5° below Mars, the 18%-lit waning crescent rises around 40 minutes before the Sun above the southeast horizon.

By 31 March, all three planets are contained within an area 6° across. Venus appears east of the group on this date, shining at mag. −4.2 and the easiest to see by far. Meanwhile, Saturn remains at mag. +0.9, just 3° from Venus with mag. +1.1 Mars now 3.3° from Saturn.

As March transitions into April, Venus leaves Mars and Saturn, the dimmer pair reducing their separation to just 19 arcseconds on 5 April. On that date, it will be possible to catch all three planets rising around the same time, approximately 80 minutes before the Sun above the east-southeast horizon.



▲ Look through 7x50 binoculars on 31 March at 05:00 UT to catch three planets

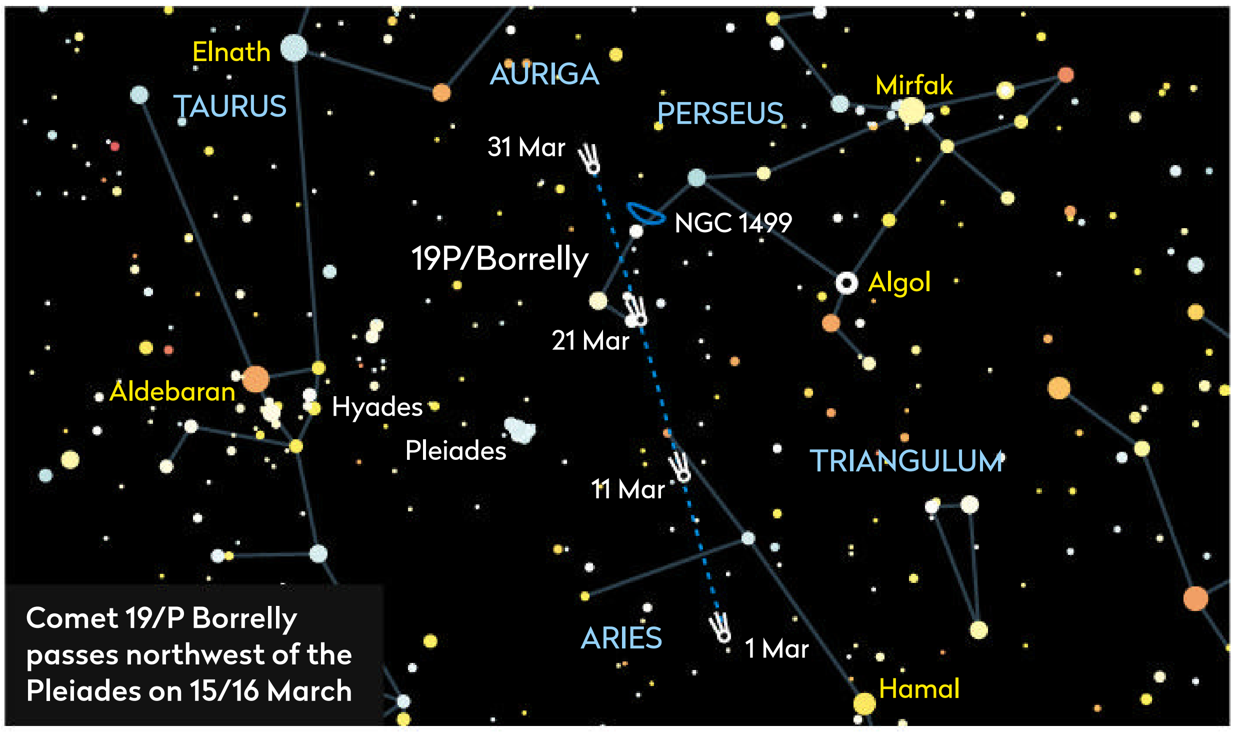
ALL PICTURES: PETE LAWRENCE

Tracking Comet 19P/Borrelly

BEST TIME TO SEE: 1–4 March and 20–31 March, avoiding the Moon

Comet 19P/Borrelly was at its brightest last month, the comet reaching perihelion on 1 February. At its peak it was expected to reach mag. +8.9, making it a binocular target. As we head into March, the comet may just remain within binocular range, but it is dimming. On 1 March, Borrelly shines with a predicted integrated magnitude of mag. +9.5, about 15˚ to the west of the Pleiades open cluster, in the middle of Aries, the Ram.

It's currently tracking northeast, passing 4˚ to the south of the mag. +3.6 triple star system 41 Arietis on the night of 3/4 March. By 12 March, Borrelly's magnitude will have reduced to mag. +10.0. At 00:00 UT on the 12th, the comet is about 8˚ to the west-northwest of the Pleiades. On the nights of 13/14 and 14/15 March, it passes close to the mag. +4.5 TYC 1796-1306-1 in Aries, an orange coloured star. If Borrelly is showing the greenish hue associated with comets, this should make a nice colour contrast, despite the large difference in brightness between the two.



Comet 19/P Borrelly passes northwest of the Pleiades on 15/16 March

Closest approach to the Pleiades occurs on the night of 15/16 March, the comet expected to be around mag. +10.1 at this time as it passes 7˚ to the northwest of the cluster. On the 21/22 March, Borrelly will lie about one-third of a degree north of mag. +3.8 Omicron (ο) Persei.

Its northeast track takes it up towards NGC 1499, the California Nebula. It lies a couple of degrees to the south of the nebula on the 26/27 March, moving within one degree of its eastern edge on the 28/29 March, when Borrelly is expected to have faded to around 11th magnitude.

Porrima's occultation

BEST TIME TO SEE: 19 March from 04:30 UT

The Moon will occult the mag. +2.7 binary star Porrima (Gamma (γ) Virginis) on the morning of 19 March. This will be an interesting and challenging occultation to observe because the sky will appear quite bright as sunrise approaches.

The best strategy will be to locate Porrima early, say from 04:30 UT. The Moon's phase will be full at the time of the occultation, so use some optical assistance to see the star, such as binoculars or a telescope finder. At 04:30 UT, Porrima lies 0.6˚ from the Moon's limb.

As the occultation approaches, it'll get harder to see the star, but a telescope should still show it even though the sky is becoming blue. Occultation disappearance occurs around 05:52 UT as seen from the centre of the UK, with reappearance occurring around 06:24 UT after sunrise.

As the occultation chord – the apparent path of the star behind the Moon – is close to the Moon's northern limb, times will vary by a number of minutes depending on location. If you do have clear skies, this is a fascinating event to observe, forcing you to do battle with the Moon's glare and the bright morning twilight just before the Sun rises.

From the centre of the UK, Porrima is occulted at 05:52 UT on 19 March as the sky is brightening due to the approach of dawn

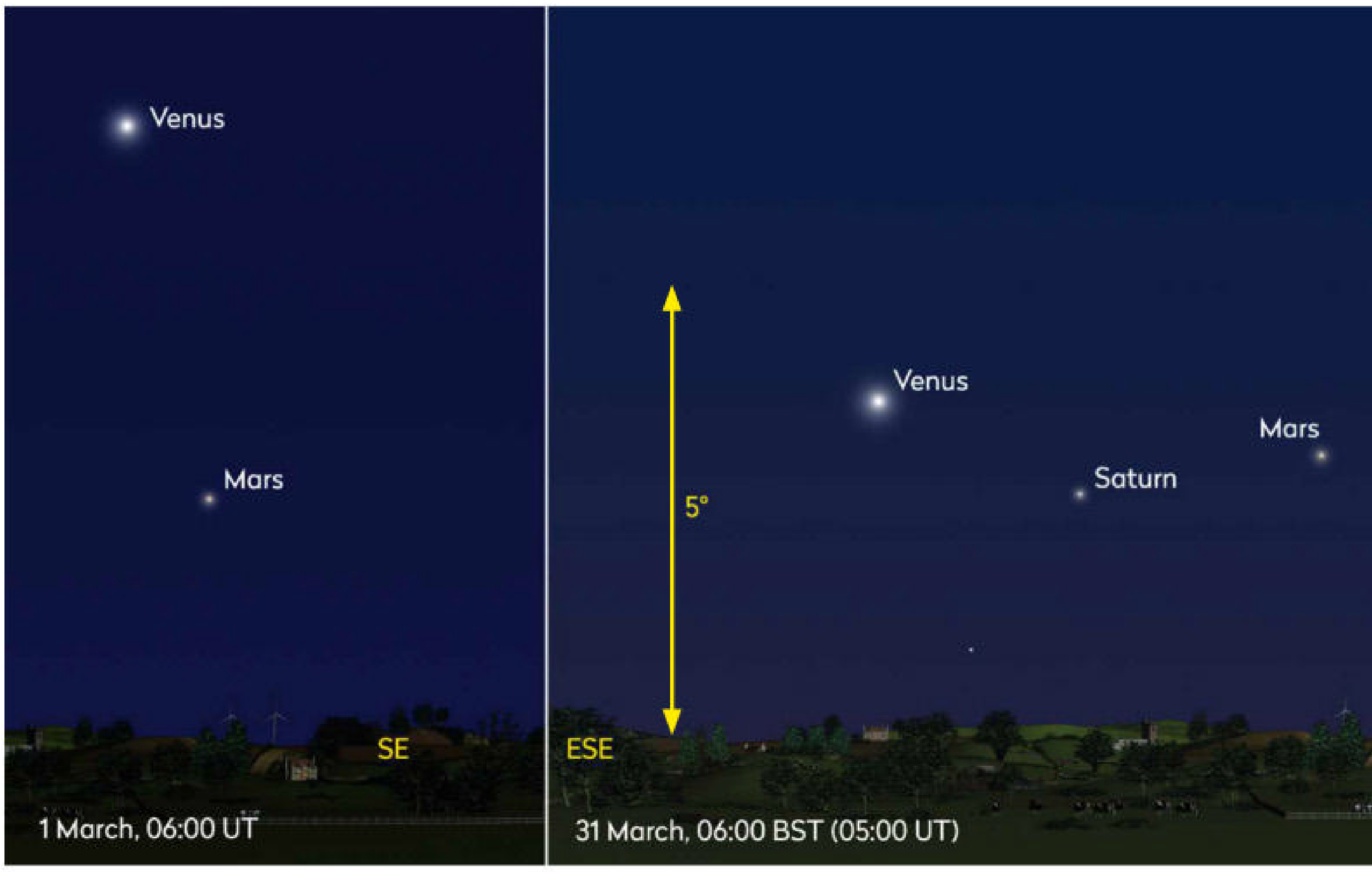
The time of occultation will vary by up to several minutes depending on location

THE PLANETS Our celestial neighbourhood in March

PICK OF THE MONTH

Venus

Best time to see: 1 March, 40 minutes before sunrise
Altitude: 10˚ (low)
Location: Sagittarius
Direction: Southeast
Features: Phase, faint shaded markings.
Recommended equipment: 75mm, or larger



▲ Venus will appear brighter against a darker sky at the start of the month

Venus is a morning object at present, rising a couple of hours before the Sun at the month's start and 80 minutes before the Sun at the end. The planet reaches dichotomy this month, passing from crescent through to gibbous phase. Dichotomy is the term used to indicate when a planet (or the Moon) reaches the 50 per cent phase. This month, dichotomy should occur on 21 March, but due to what's known as the 'phase anomaly', through the eyepiece of a telescope Venus will appear half-lit a few days later than this theoretical prediction. The phase anomaly is believed to be caused by how the planet's thick atmosphere scatters sunlight. Take a look through a telescope and make an estimate of the phase in the run up towards and beyond the 21st.

Venus drops in brightness over March, but only by a fifth of a magnitude. On the 1st this most brilliant of planets appears to shine at mag. –4.4. On the 31st, at mag. –4.2, Venus will still look intense against the morning's dawn twilight. It appears best at the month's start with a darker sky.

Mars and Saturn appear close to Venus. Saturn will be too close to the Sun to see properly at the month's start, but it will be visible with Venus and Mars at the month's end. On the 25th, Venus sits 4.6˚ from mag. +1.1 Mars, and 4.1˚ from +0.9 Saturn, but the squat triangle formed by the three fails to gain much altitude above the southeast horizon as sunrise approaches. An 18%-lit waning crescent Moon lies below the trio on the morning of the 28th.

▲ Venus should reach a 50 per cent phase around 21 March, but may appear like this later

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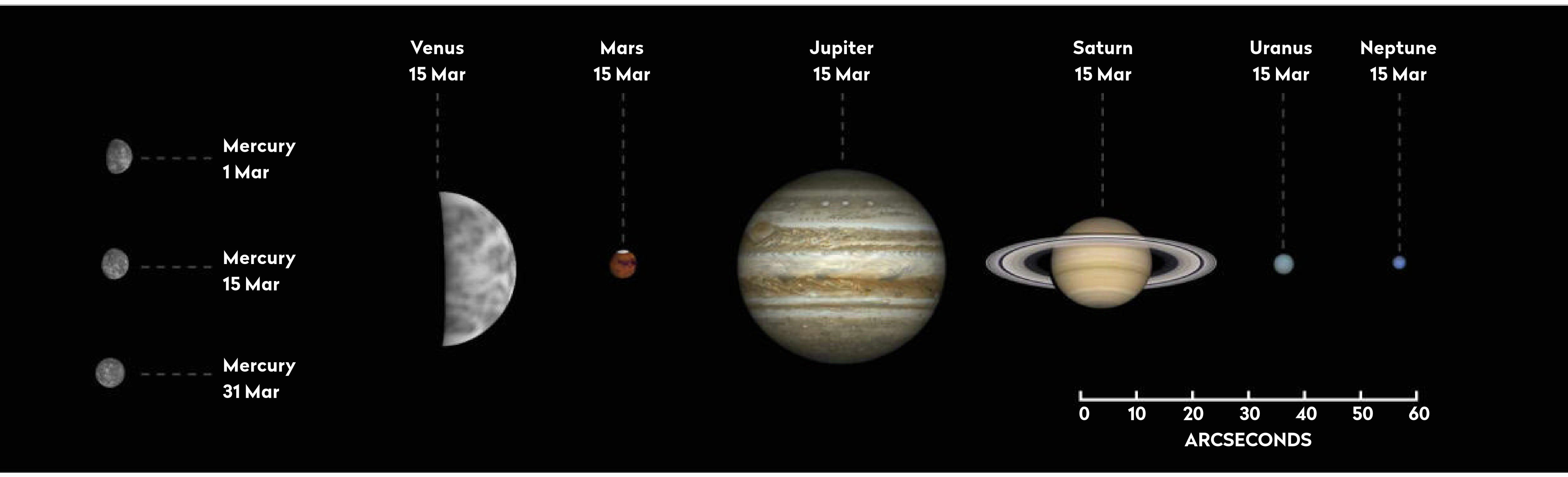
The planets in March

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Mercury

Mercury is a morning planet, not well placed at the start of March. On the 1st it shines at mag. –0.1, lies 2° southwest of mag. +0.9 Saturn and rises 30 minutes before the Sun. That offset deteriorates over the following days, and as a consequence, from the UK at least, Mercury is unlikely to be seen with the naked eye over the rest of the month.

Mars

Best time to see: 31 March, 50 minutes before sunrise
Altitude: 3° (very low)
Location: Capricornus
Direction: Southeast

Mars is visible in the morning sky as a mag. +1.3 object rising 90 minutes before the Sun on the 1st, when it appears 5° below mag. –4.4 Venus. Over the next few mornings, Mars and Venus appear to converge, both planets appearing separated by just 4° on the 12th. A lovely, albeit rather low, triangular grouping of Mars, Venus and Saturn can be seen low above the southeast horizon 40 minutes prior to sunrise on the 24th. By the 31st, Mars will have brightened to mag. +1.1 and rises 80 minutes before the Sun. The Mars, Saturn and Venus triangle will be contained to an area less than 6° across on 31 March.

Through an eyepiece Mars is a bit disappointing, appearing to have an apparent diameter of 5 arcseconds at the month's end. However, this will change during the year as Mars approaches opposition in early December 2022.

Jupiter

Jupiter reaches solar conjunction on 5 March and despite drawing away from the Sun's position rapidly, is unlikely to be seen this month. On 31 March, mag. –1.9 Jupiter rises just 20 minutes before the Sun.

Saturn

Best time to see: 31 March, 50 minutes before sunrise
Altitude: 3° (very low)
Location: Capricornus
Direction: East-southeast

Saturn is a morning planet, slowly crawling away from the Sun during the month. Its placement in the sky isn't very optimal at present, the planet not gaining much altitude despite rising at a reasonable time before the Sun. If you have a flat southeast horizon, look out for mag. +0.9 Saturn, mag. +1.1 Mars and mag. –4.2 Venus together between 22–31 March. A thin, 18%-lit waning crescent Moon sits below the trio on the morning of the 28th.

Uranus

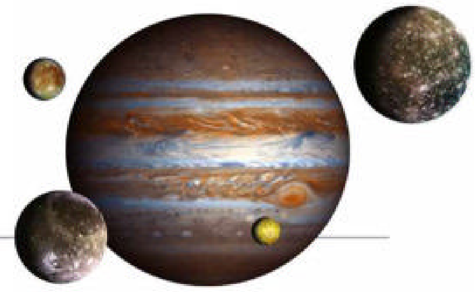
Best time to see: 1 March, 19:50 UT
Altitude: 33°
Location: Aries
Direction: West-southwest

Mag. +7.9 Uranus may be seen 30° above the west-southwest horizon as true darkness arrives on the 1st. A 17%-lit waxing crescent Moon sits 6.5° to the southwest of Uranus on the evening of the 6th, and as a 25%-lit waxing crescent, 6° to the planet's east on the 7th. By mid-March, Uranus appears a fraction over 20° up above the western horizon as true darkness descends, but by the month's end it falls to just 8°. As a result, March marks the end of the current observational window for this distant world.

Neptune

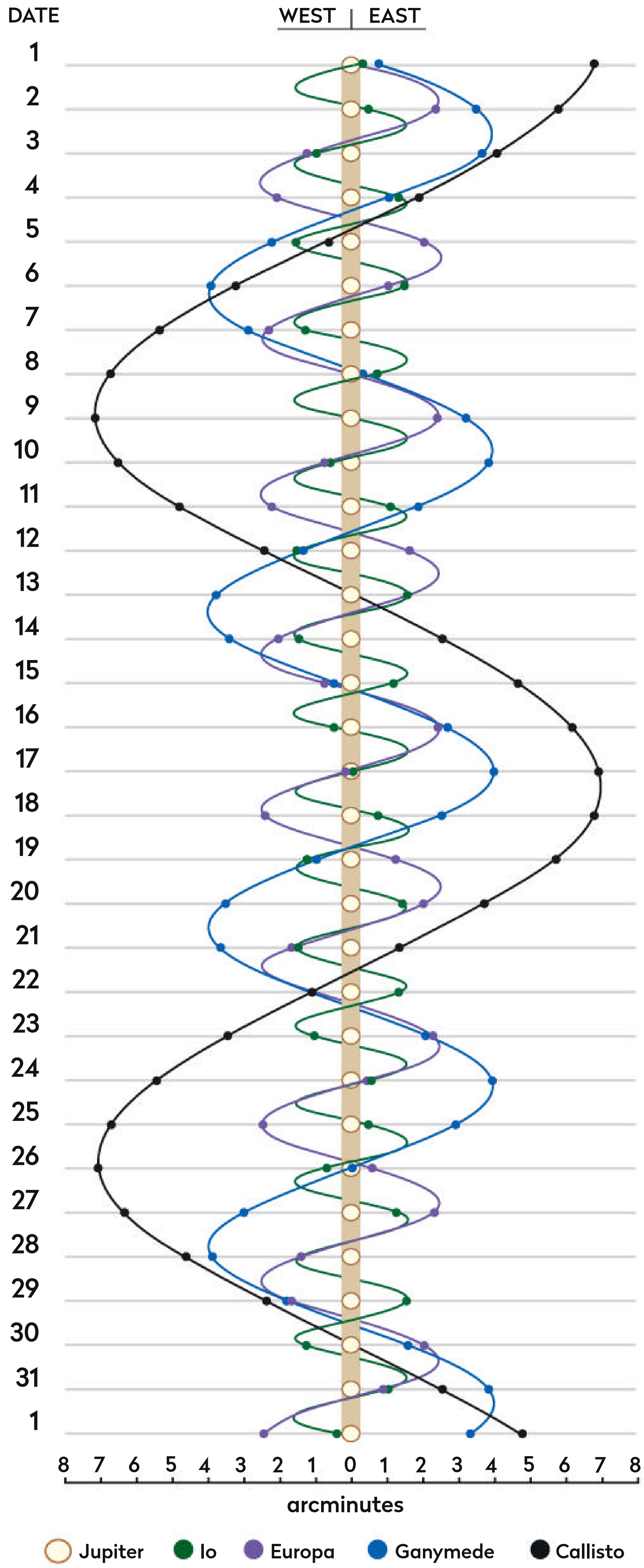
Neptune is in conjunction with the Sun on 13 March; consequently, the planet is not visible this month.

More ONLINE
Print out observing forms for recording planetary events



JUPITER'S MOONS: MARCH

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – MARCH

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

Arcturus	STAR NAME
PERSEUS	CONSTELLATION NAME
	GALAXY
	OPEN CLUSTER
	GLOBULAR CLUSTER
	PLANETARY NEBULA
	DIFFUSE NEBULOSITY
	DOUBLE STAR
	VARIABLE STAR
	THE MOON, SHOWING PHASE
	COMET TRACK
	ASTEROID TRACK
	STAR-HOPPING PATH
	METEOR RADIANT
Circlet	ASTERISM
	PLANET
	QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

N 5° E W S — COMPASS AND FIELD OF VIEW

MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

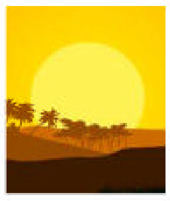
1 March at 00:00 UT
15 March at 23:00 UT
31 March at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in March*



Date	Sunrise	Sunset
1 Mar 2022	06:58 UT	17:48 UT
11 Mar 2022	06:35 UT	18:07 UT
21 Mar 2022	06:10 UT	18:25 UT
31 Mar 2022	06:46 BST	19:43 BST

Moonrise in March*

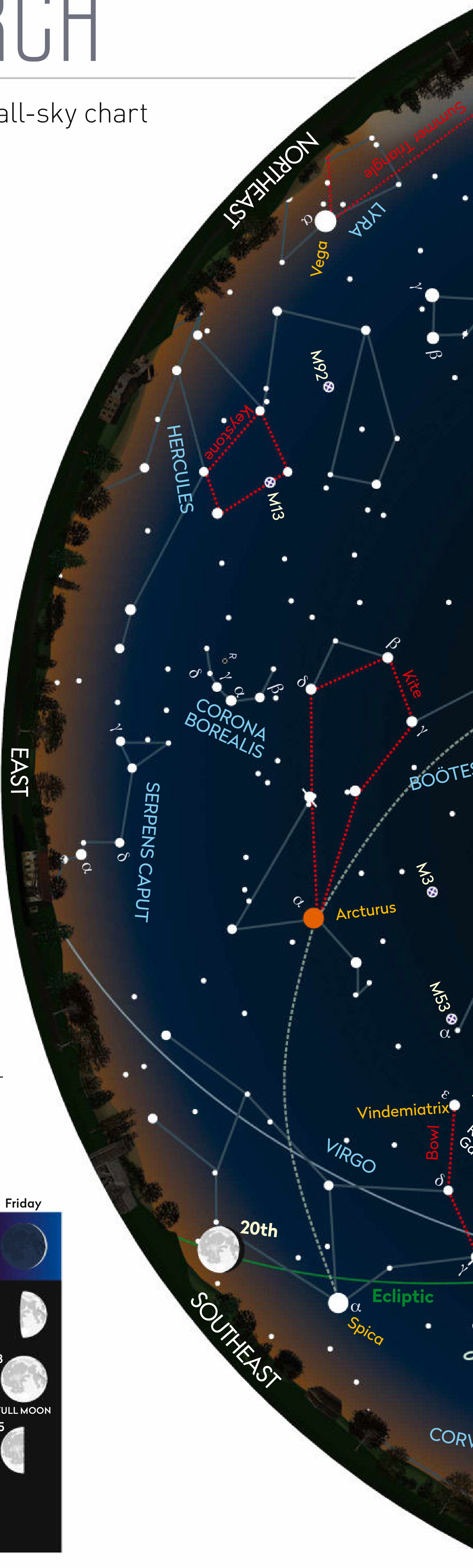
Moonrise times

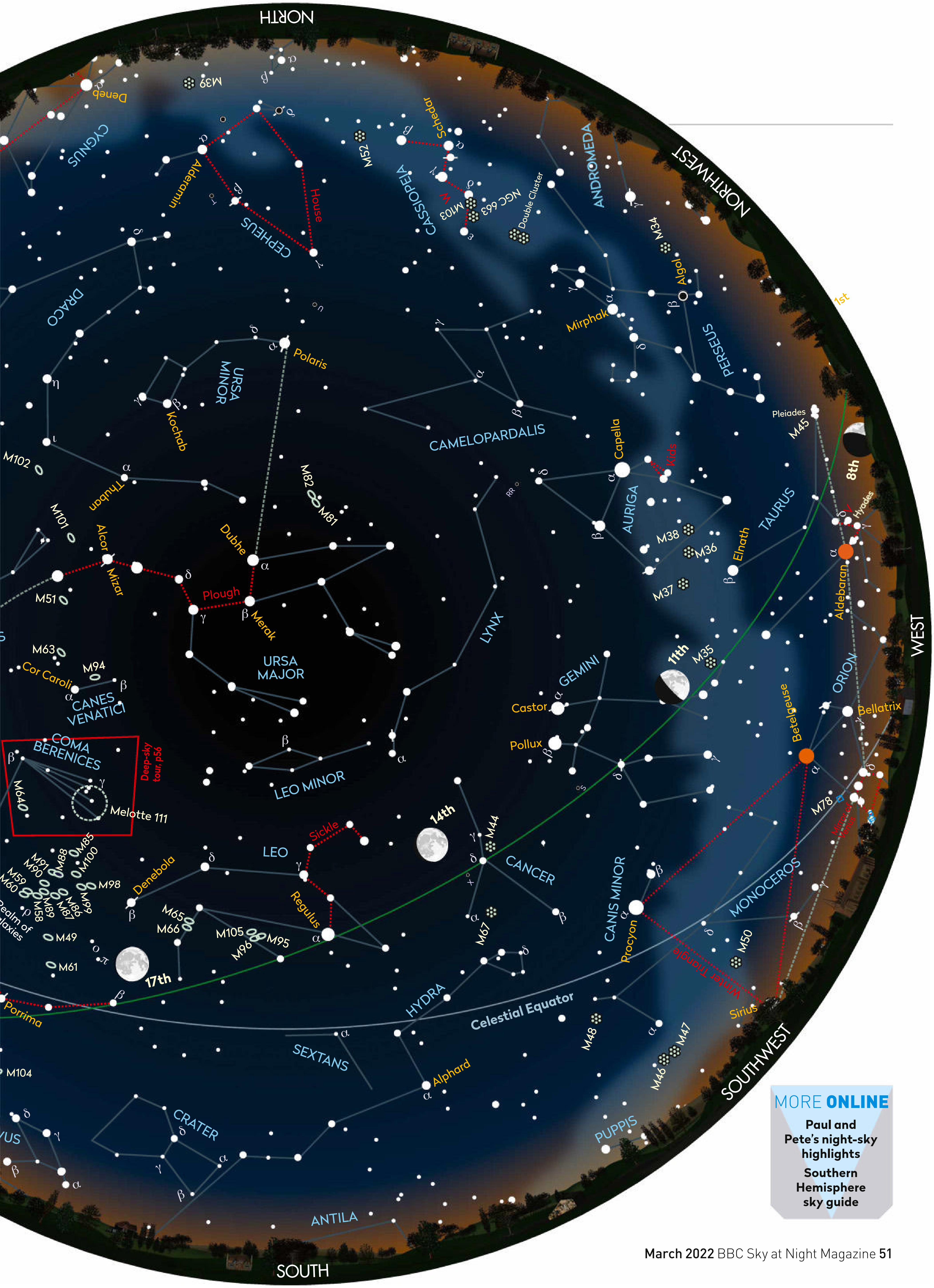
1 Mar 2022, 07:09 UT	17 Mar 2022, 17:15 UT
5 Mar 2022, 08:06 UT	21 Mar 2022, 22:53 UT
9 Mar 2022, 09:07 UT	25 Mar 2022, 03:06 UT
13 Mar 2022, 12:05 UT	29 Mar 2022, 06:34 BST

*Times correct for the centre of the UK

Lunar phases in March

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
			1	2 NEW MOON	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18 FULL MOON
19	20	21	22	23	24	25
26	27	28	29	30	31	



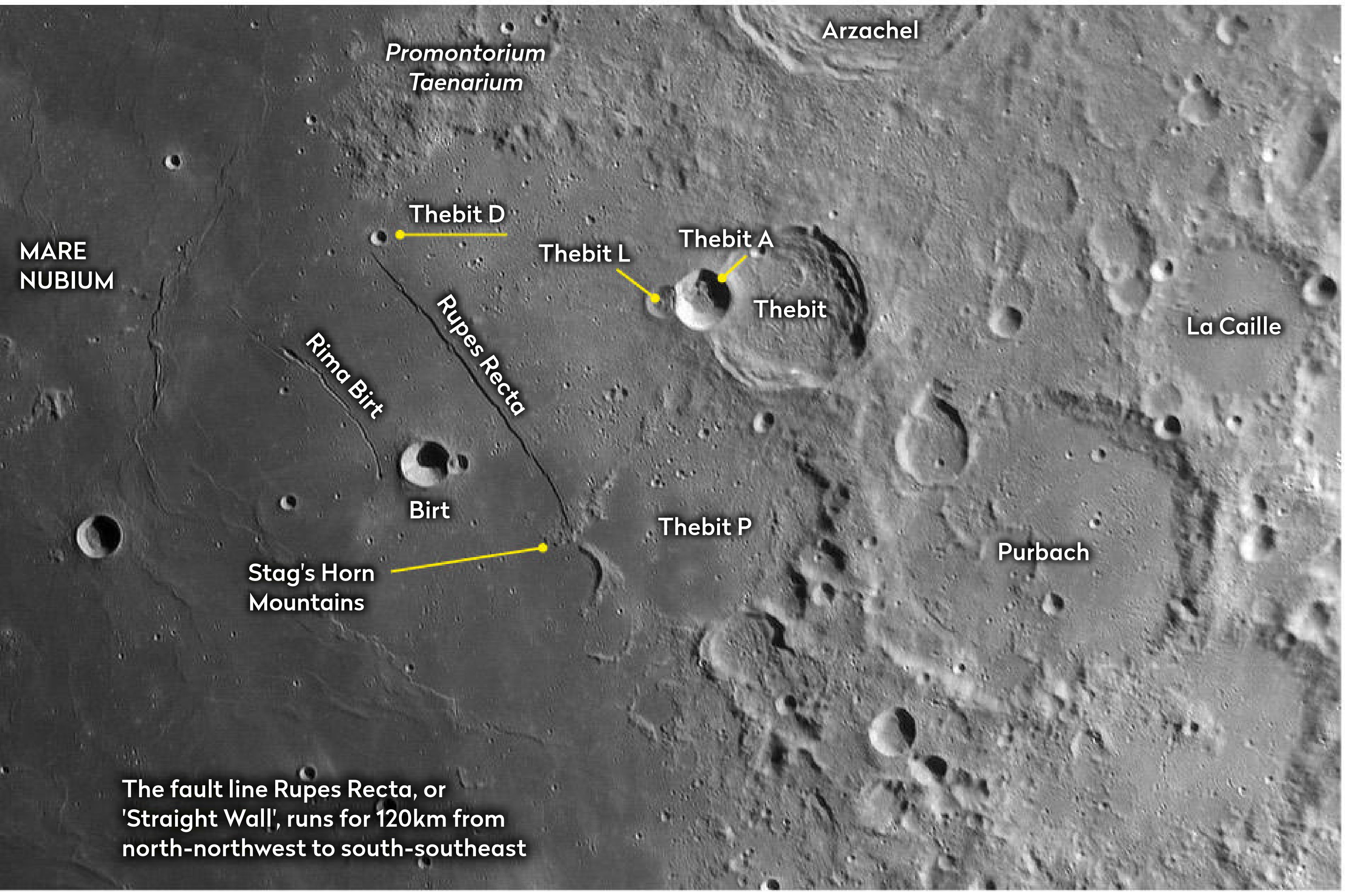


MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH March's top lunar feature to observe

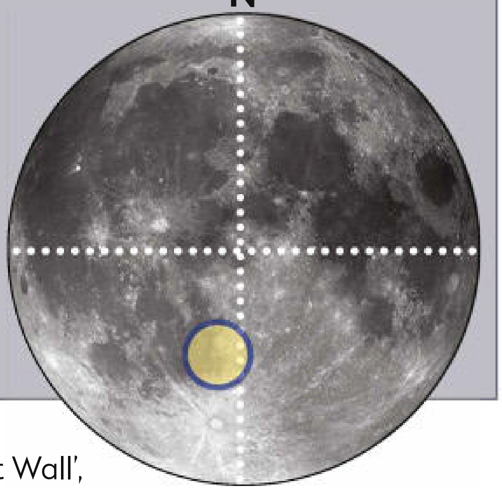


The fault line Rupes Recta, or 'Straight Wall', runs for 120km from north-northwest to south-southeast

Rupes Recta

Type: Fault line
Size: Length 120km, width 2-3km
Longitude/Latitude: 7.7° W, 21.7° S
Age: Approximately 3.2–3.9 billion years
Best time to see: One day after first quarter (11 March) or last quarter (25 March)
Minimum equipment: 50mm refractor

N



Rupes Recta, also known as the 'Straight Wall', is a remarkable feature on the Moon's surface. Illuminated by morning light, it looks like a dark scratch, low resolution photos making it appear like a hair has crept into the image. In the period up to last quarter, Rupes Recta takes on a different persona, appearing as a bright line.

The variation is due to the fact that the Straight Wall forms a sloped transition from an upper surface level in the east to a lower one in the west. Viewed through a telescope, this gives the impression of a steep cliff. Rupes Recta means 'straight cliff'.

However, as is often the case with stark light and shadow effects on the Moon's surface, the cliff-like appearance of Rupes Recta is misleading. Measurements of the difference in height between surfaces suggests the vertical height of the 'cliff' to be less than half-a-kilometre, probably in the range of 400–500m. Doing the maths, this gives a slope angle of just 21° – hardly a cliff!

The Straight Wall is a fault line across the lunar surface. Running for 120km from north-northwest to south-southeast, Rupes Recta appears straight and an alternative name sometimes used to describe it is 'the railroad'. It appears uninterrupted by younger impacts, although high-resolution views and images of the fault line show kinks along its length. These appear to be features associated with the fault line itself rather than secondary external events. Measured from the northern end, the kinks occur at distances of 15km, 25km, 42km and 86km. Close up images taken with the LRO (Lunar Reconnaissance Orbiter) suggest the kinks represent parts of the fault where one section has petered out and another started, along the same trajectory.

Rupes Recta sits in a southeast region of **Mare Nubium**, inside a feature that resembles a large crater, 185km in diameter. This is an unnamed feature which may just be an illusion caused by rounded highland sections to the north and southeast, with the other 'rim section' hinted at by wrinkle ridges in the mare to the west. The Straight Wall runs between 58km **Thebit** to the east and 17km **Birt** to the west.

The northern end of the fault begins adjacent to 5km **Thebit D**, itself lying just south of one of the highland regions mentioned earlier, an outcrop named **Promontorium Taenarium**. The other end of Rupes Recta passes across a raised mountain range, which includes a small, 17km crescent-shaped range. The peaks here are known as the **Stag's Horn Mountains**.

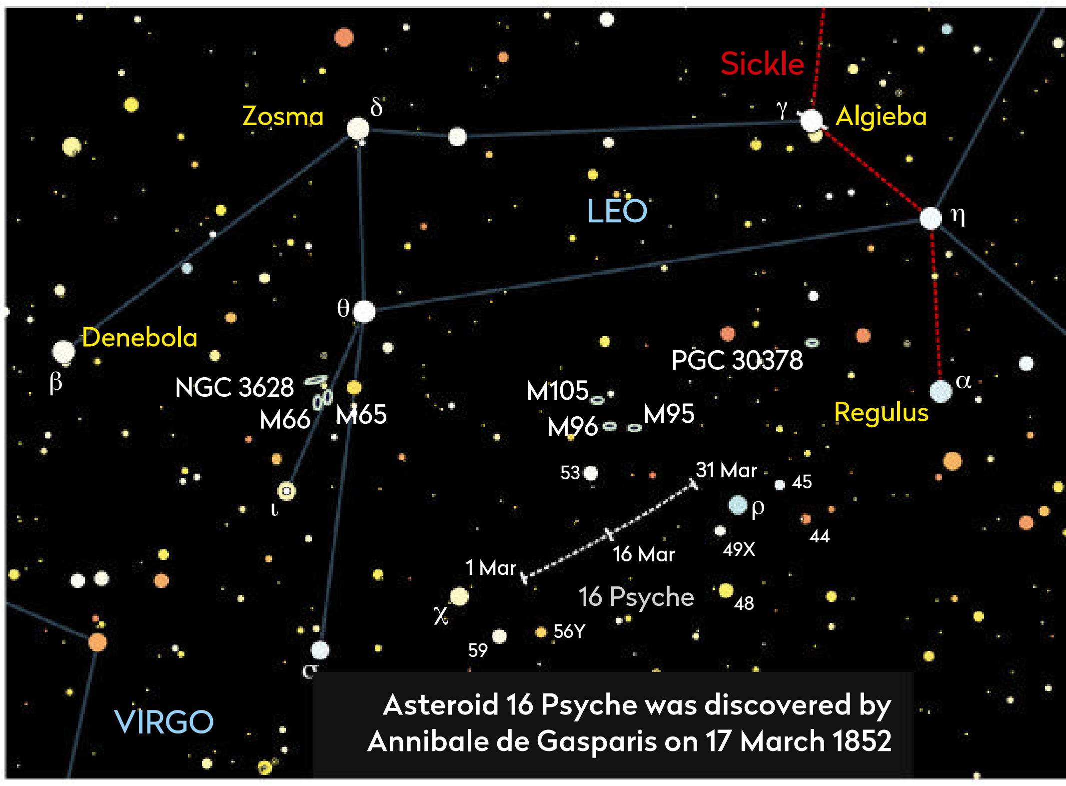
Rupes Recta sits in a feature that resembles a large crater, 185km in diameter

With a large telescope setup (300mm or larger), you may like to try for a narrow rille which starts to the west of Birt and gently arcs northwest, roughly parallel to Rupes Recta. Known as **Rima Birt**, it is around 1.5km wide and runs for 50km.

PETE LAWRENCE X 3

COMETS AND ASTEROIDS

Asteroid 16 Psyche reaches opposition in the constellation of Leo, the Lion



Asteroid 16 Psyche was discovered by Annibale de Gasparis on 17 March 1852

Asteroid 16 Psyche reaches opposition on 3 March when it can be found shining at mag. +10.4 in the belly of Leo, the Lion. At 00:00 UT on 1 March, Psyche appears at mag. +10.5 and forms the northeast vertex of an equilateral triangle with mag. +4.6 Chi (χ) Leonis and the mag. +5.0 star 59 Leonis. It subsequently tracks west-northwest, brightening to mag. +10.4 on 2 March, a level it maintains until the 5th. It then starts to dim, ending the month at mag. +11.1. At this time, it will be located 1.5˚ east-northeast of variable Rho (ρ) Leonis. This star exhibits a small brightness variation between mag. +3.8 and mag. +3.9. Psyche's position at the end of the month places it around 3˚ to the southwest of the galaxy trio M95, M96 and M105.

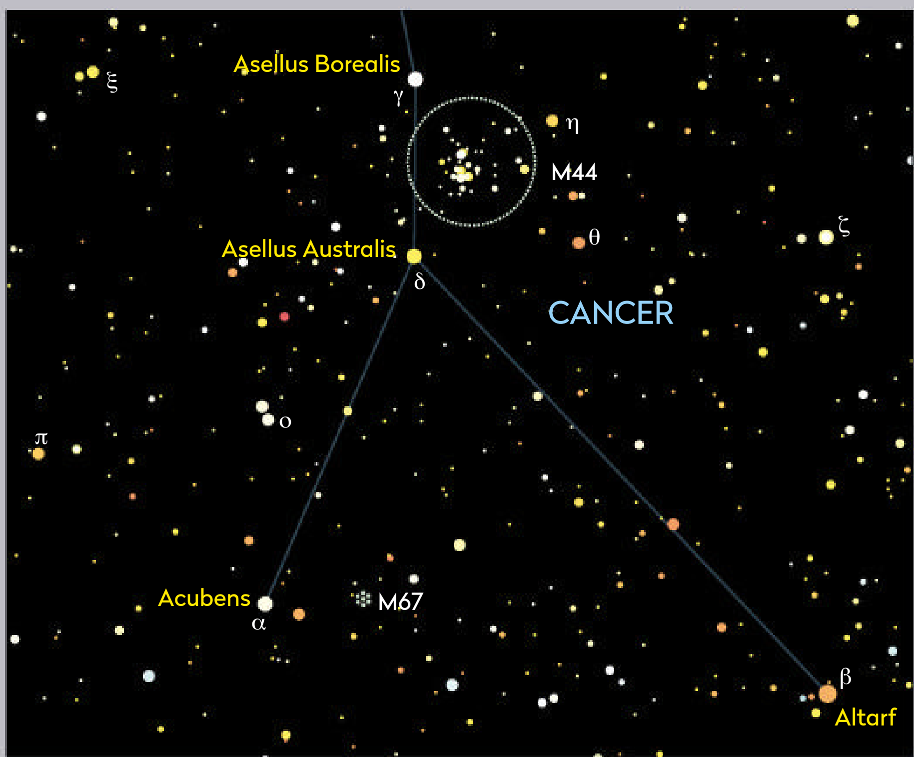
Psyche has a diameter of 200km and is thought to be the remnant iron core of a failed planet, a protoplanet. This is a body which formed out of the Solar System's original protoplanetary disc and had enough mass to undergo its own internal melting and deformation. The result is a massive object, Psyche ranking as one of the ten most massive asteroids known. It's so massive that its gravitational effect on other asteroids can be used to measure its mass. This has been determined as 2.72×10^{19} kg.

Psyche's orbit takes 4.99 years to complete, its passage around the Sun taking place at an average distance of 2.9 AU. It rotates relatively quickly, completing one rotation every 4.2 hours. It is believed to be potato-shaped, measuring 279km x 232km x 189km. Its size and shape were partly calculated by compiling the results of over 100 occultation events involving distant stars.

STAR OF THE MONTH

Find Altarf, at the end of the Crab's leg

▼ The brightest star in Cancer is Altarf (Beta (β) Cancri), which is 290 lightyears away



As a constellation, it has to be said that Cancer isn't one of the most impressive. Yes, it contains the open cluster M44, also known as the Beehive Cluster, and there's another fainter open cluster near Acubens (Alpha (α) Cancri) called M67, but the stars that form the Zodiacal Crab of Cancer are pretty faint.

The brightest isn't Acubens as you might think, but Altarf (Beta (β) Cancri) which marks the southwest point of the constellation's inverted Y-shaped pattern. The name is from the Arabic *'Al Tarf'* meaning 'the End', and it represents one of the Crab's legs.

Altarf has a spectral type of K4III Ba1, a cool orange K4 class giant with abundances of barium (chemical symbol Ba). Its effective temperature is 3,717˚C, which is much cooler than our Sun at 5,505˚C.

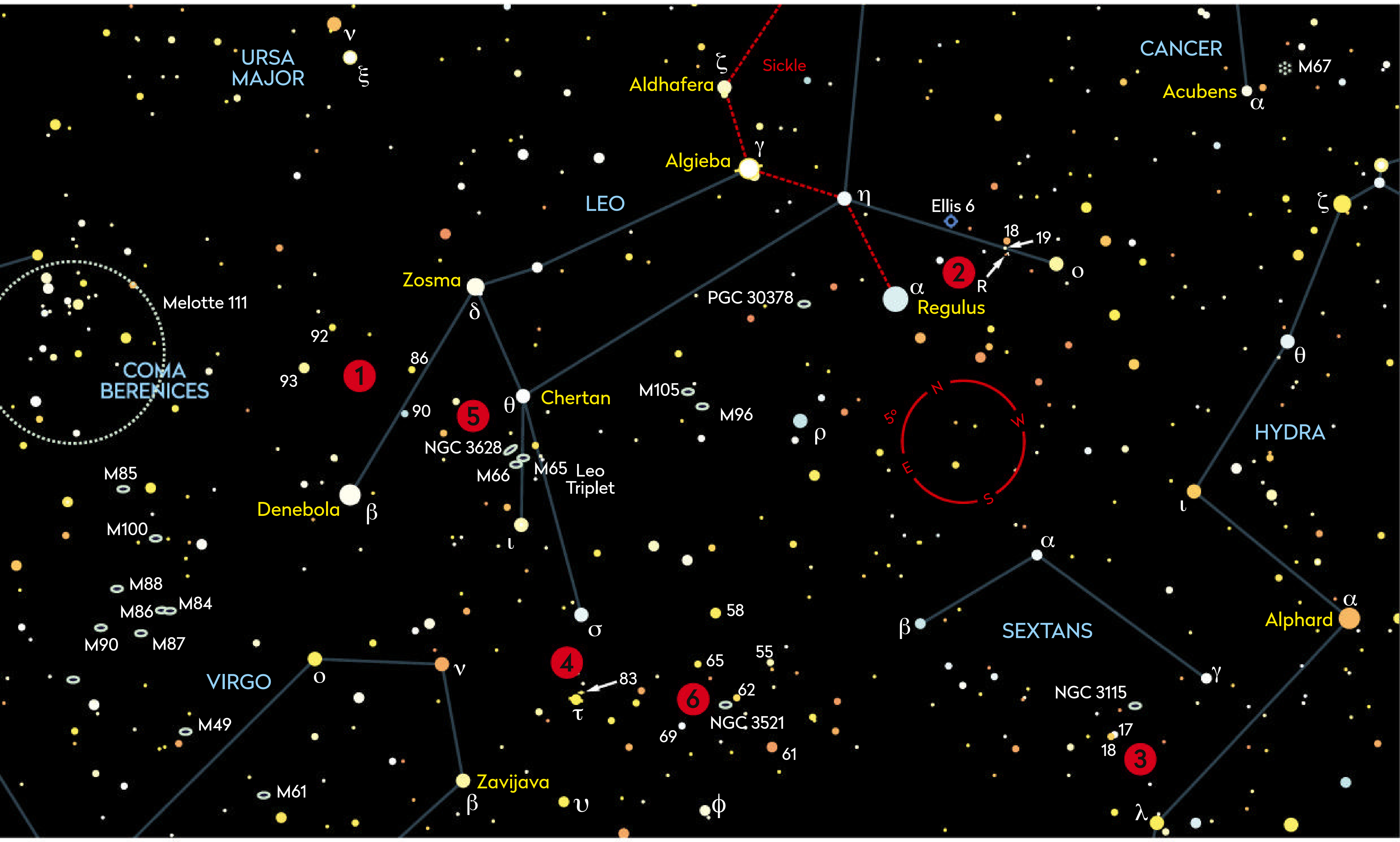
Located at a distance of 290 lightyears, Altarf shines at mag. +3.5. Despite its diminutive status, it should be borne in mind that Altarf is still 61 times larger and 870 times more luminous than the Sun.

A faint red-dwarf companion accompanies the main star. Shining at 14th magnitude, it is estimated to lie around 2,600 AU from Altarf; that's around 65 times the Sun-Pluto distance. The orbital period is estimated to be 76,000 years, but no evidence for any mutual orbital motion has been confirmed yet.

Altarf is also believed to have a planet. Discovered in 2014, this body is estimated to be nearly eight times the mass of Jupiter, orbiting the star once every 605 days at an average distance of 1.7 AU.

BINOCULAR TOUR With Steve Tonkin

This month's highlights include a Double Double in Leo and a galaxy triplet



1. 86 Leo Starfield

10x50 We'll start this month's tour with a colourful starfield. Locate the orange-yellow mag +5.6 star 86 Leonis between Denebola (Beta (β) Leonis) and Zosma (Delta (δ) Leonis), and compare its colour to brilliant-white 90 Leonis that is 2° back towards Denebola. There is also a multicoloured curved string of 7th and 8th magnitude stars that extends 3° eastward from 86 Leo, and the region encompassing 92 Leo and 93 Leo is also very rewarding if you like coloured stars. ☐ **SEEN IT**

2. R Leonis

10x50 R Leonis is a Mira-type variable star, with a magnitude ranging from +10.1 to +5.9 over a 313-day cycle. To locate it, first identify the mag. +5.6 star 18 Leonis and mag. +6.5 19 Leonis. Next, 8 arcminutes south of 19 Leonis is a pair of stars, with R Leonis more easterly. R Leonis is about to start brightening again, so it's a good time to start viewing it. ☐ **SEEN IT**

3. 17 and 18 Sextantis

10x50 Look about 4.5° east of mag. +5.1 Gamma (γ) Sextans where you will find a widely separated (12 arcminutes) pair of stars, which make an easy double star for small binoculars. The more easterly one, orange 18 Sextantis, shines at mag. +5.6, and its white companion, 17 Sextantis is slightly fainter at mag. +5.9. There are three fainter colourful binocular doubles within 1.5° to the north, but none of these are as close in magnitude. ☐ **SEEN IT**

4. Leo's Double Double

10x50 Use the chart to identify and locate mag. +4.9 Tau (τ) Leonis. One third of a degree to the north-west is its mag. +6.5 companion, 83 Leonis. Look carefully and you will see that each of these is a double star with a mag. +7.5 companion. Tau Leonis's pale companion is easier to discern at 1.5 arcminutes but, at only 29 arcseconds, splitting 83 Leonis is a stiff challenge for 10x50 binoculars. ☐ **SEEN IT**

5. Leo Galaxy Triplet

15x70 You'll need a dark transparent sky for our final targets. If you put mag. +3.3 Chort (Theta (θ) Leonis) outside the northwest of the field of view of 15x70 binoculars, the galaxies will be in the centre. You may need averted vision at first, but once you are familiar with their appearance they become easier to see, but you will still need averted vision to discern NGC 3628's different shape. ☐ **SEEN IT**

6. NGC 3521

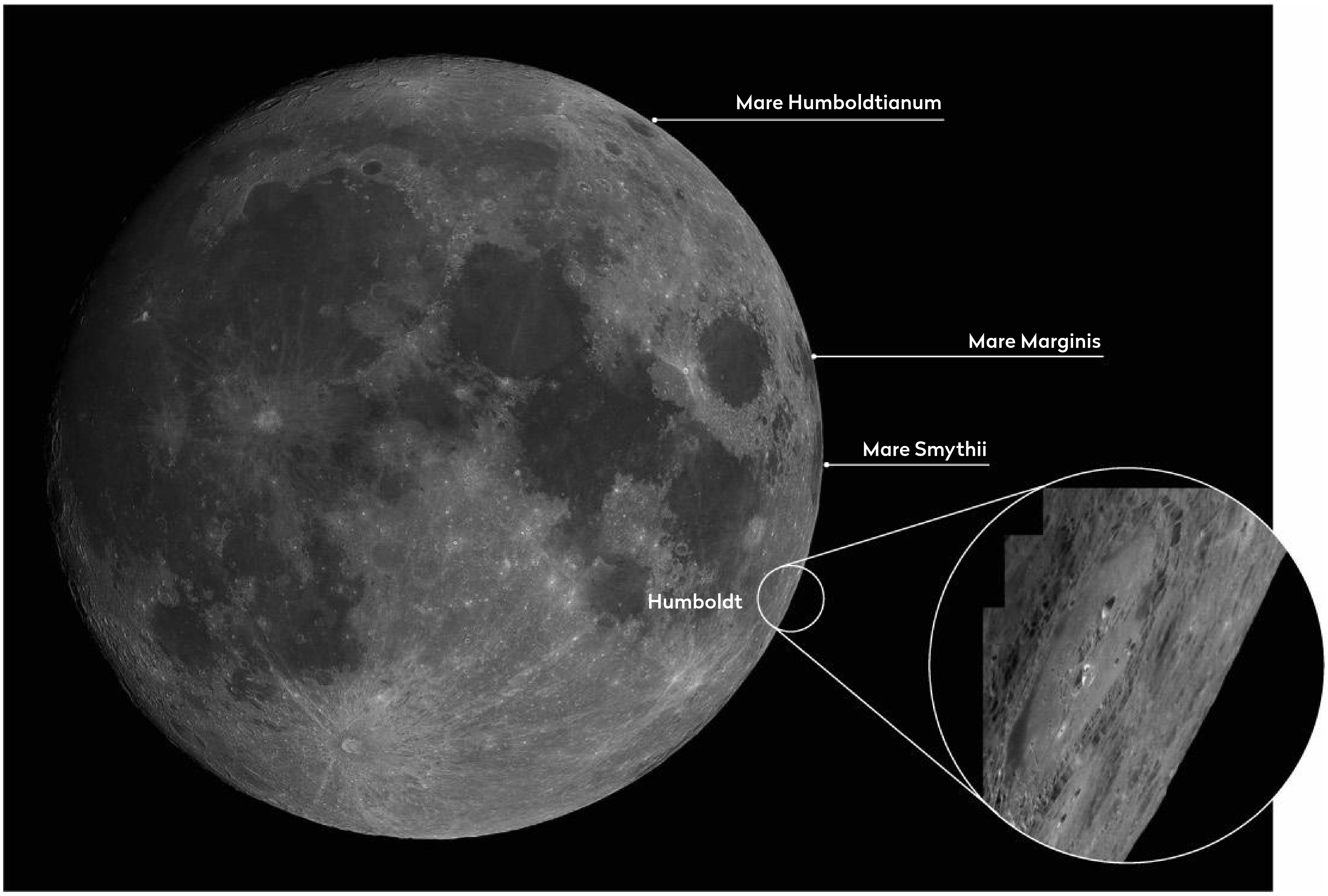
15x70 Next is a galaxy that is a bit "off the beaten track", as there aren't nearby bright marker stars. You've already found Tau Leonis, so use that in conjunction with the chart to find 65 Leonis (mag. +5.5) and 69 Leonis (mag. +5.4). Put them near the north and east edge respectively of your field of view, and NGC 3521 will be near the middle. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you spot the Moon's eastern libration features this month?



▲ **This month is a good opportunity to see the Moon's eastern limb libration features, which become visible as a result of the Moon's rocking motion; these include three seas, Mare Humboldtianum, Mare Marginis and Mare Smythii, and the 207km crater Humboldt (inset)**

The Moon is tidally locked to Earth, rotating once on its axis in the same time it takes to complete each orbit. From Earth this means we get to see the same familiar features revealed and hidden as the Moon passes through its phase cycle. Looking at the Moon at higher magnification reveals that there is slight variation in this view. This month's challenge is to take advantage of this effect to spot some tricky edge features.

The variation is mostly caused by the Moon's elliptical and tilted orbit. The ellipticity causes a variation in the Moon's orbital speed which allows us to see slightly further round the eastern or western side of the Moon's globe. The tilt causes the Moon to bob up and down relative to the plane of Earth's orbit (the ecliptic plane). The tilt isn't much at around 5°, but it does allow us to see further round the Moon's southern and northern edges.

The variations are collectively known as lunar libration and over time 59 per cent of the Moon's globe can be seen. Actually, seeing 59 per cent of the Moon's globe is easier said than done as in order to see a specific edge feature, the libration has to be favourable as does the lunar phase. In addition, the Moon has to be above your horizon and, of course, the weather has to play ball.

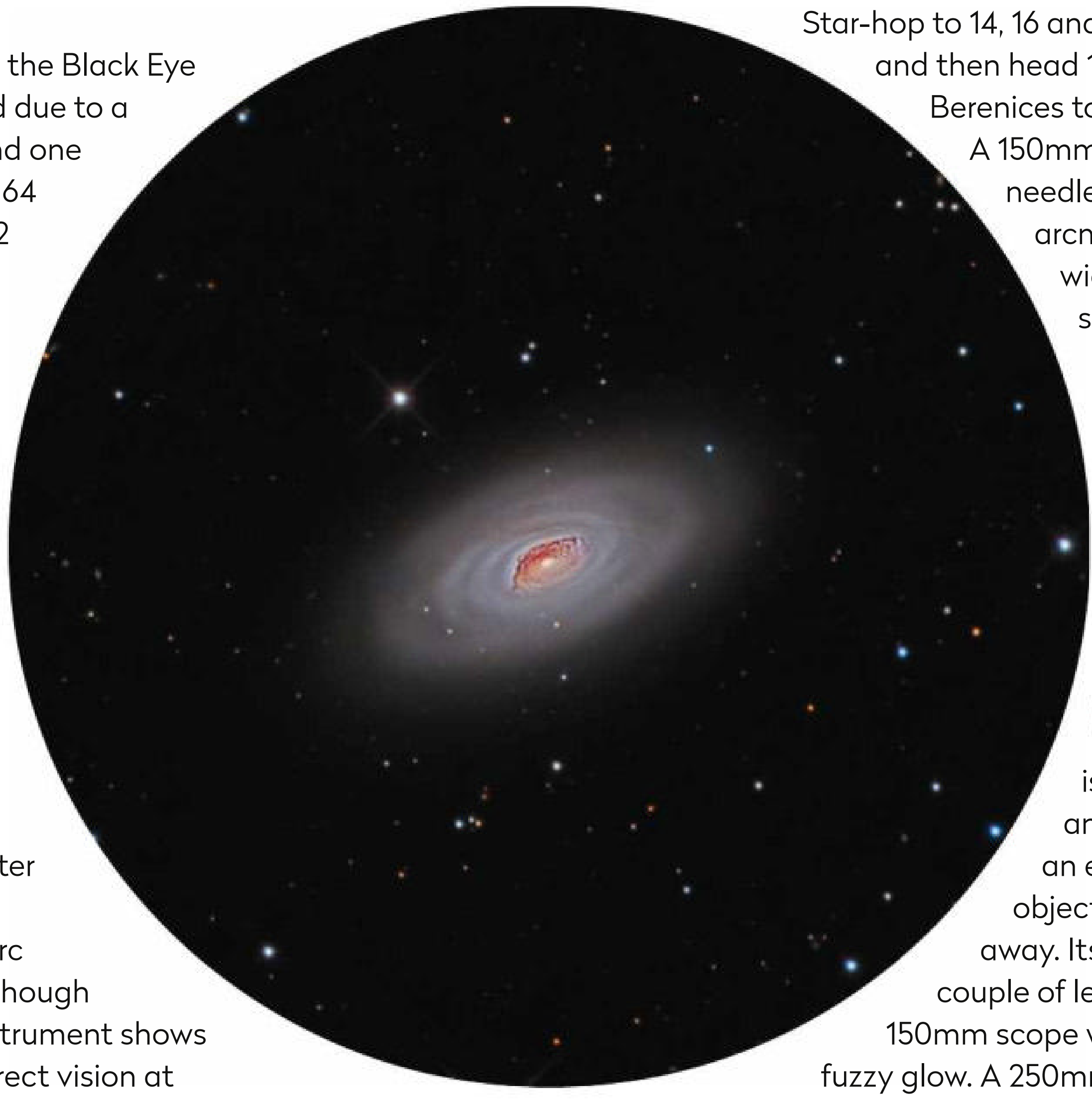
This month there is a good opportunity to spot eastern libration features; lunar features which can only be seen under favourable libration. The very thin, 2%-lit waxing crescent Moon on the evening of 3 March shows the three eastern seas, Mare Humboldtianum, Mare Marginis and Mare Smythii. The magnificent 207km crater Humboldt is also well positioned on this date. This Moon sets 70 minutes after the Sun, so isn't an easy target.

On the evenings of the 4th and 5th, the Moon appears at a greater phase and stays up progressively longer after sunset. Libration remains favourable for the features mentioned, but starts to become less optimal after the 6th.

One aspect which does work in our favour during March is the position of the waxing Moon in the early evening sky. The ecliptic makes a steep angle with the western horizon around sunset at this time of year. Despite its orbital tilt of 5° from the ecliptic plane, the Moon tends to stay close to the ecliptic in the sky, and consequently, it's approach vector towards the western horizon in March also appears steep. This gives it a good altitude post sunset which is ideal for us when we want to observe or image it.

DEEP-SKY TOUR

Discover the celestial treasures inside Coma Berenices, the Queen's Hair



▲ M64, the Black Eye Galaxy, was discovered by English astronomer Edward Piggott on 23 March 1779

THOMAS HENNE/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 M64

We start at M64, the Black Eye Galaxy, so-called due to a dark dust lane arcing around one side of its core. To locate M64 manually, start at mag. +4.2 Beta (β) Comae Berenices. One-degree west is 41 Comae Berenices and 3° west-southwest of this star lies 35 Comae Berenices. Mag. +8.5 M64 sits one-quarter of the way along the line from 35 Comae Berenices to 41 Comae Berenices.

Smaller scopes show an elliptical glow with a prominent nucleus. A 150mm instrument reveals the dark patch, but it's fainter than photos of M64 would suggest; more like a faint arc visible with averted vision though small scopes. A 250mm instrument shows the 'black-eye' best with direct vision at 200–250x power. M64 lies 17 million lightyears away and is inclined at 60° to our line of sight. ☐ **SEEN IT**

2 NGC 4725

M64 sits to the southeast of a large naked-eye open cluster called Melotte 111, a triangular smattering of stars bright enough to form part of the Coma Berenices constellation. The top of the triangle is marked by mag. +4.3 Gamma (γ) Comae Berenices and our next target, mag. +10.1 barred-spiral galaxy, NGC 4725 sits 1.6° west and 0.6° south of this star. A small telescope shows the galaxy as an elongated glow, around 7x5 arcminutes in size, with a small core. A 300mm scope shows the core to be extended in size, its barred nature quite evident. The faint halo surrounds the core, something which becomes evident with larger apertures. ☐ **SEEN IT**

3 NGC 4565

We hop back to the east of Melotte 111 for the edge-on galaxy NGC 4565. This is a real beauty, shining at mag. +9.5. The best way to locate it is to start from Gamma Comae Berenices and head south along the eastern side of Melotte 111. Star-hop to 14, 16 and 17 Comae Berenices, and then head 1.7° east from 17 Comae Berenices to arrive at NGC 4565.

A 150mm scope shows a narrow, needle-like streak of light 7 arcminutes long, 1.5 arcminutes wide and aligned northwest-southeast. A 300mm scope more than double's the 'needle' length, also revealing a short section of the dark dust lane that runs along its edge. ☐ **SEEN IT**

4 NGC 4494

Located 1° west of NGC 4565 is mag. +9.7 NGC 4494, another galaxy but this time an elliptical. This is a distant object, 45 million lightyears away. Its designation is E1-2, just a couple of levels off a sphere (E0). A 150mm scope will show it as a 1 arcminute fuzzy glow. A 250mm scope starts to reveal a north-south elongation in its shape. NGC 4494 appears again like a glowing fuzz-ball through such an instrument, brightening at the centre, where its star-like nucleus can be found. While looking at NGC 4494 through the eyepiece, ponder how it looks in comparison to the other spiral galaxies we've seen. Ellipticals can be challenging objects! ☐ **SEEN IT**

5 NGC 4559

Next, head back to NGC 4565 and then 2° north to arrive at our next target, mag. +9.9 NGC 4559. This object can be seen clearly in a small scope but like most galaxies, it benefits from increased aperture. It's an intermediate spiral – one deemed as having a structure between that of a regular spiral and one with a barred core – which lies at a distance of 29 million lightyears. Like NGC 4565, the orientation is roughly northwest to southeast, the southeast end of the galaxy appearing to fade more abruptly than that to the northwest. ☐ **SEEN IT**

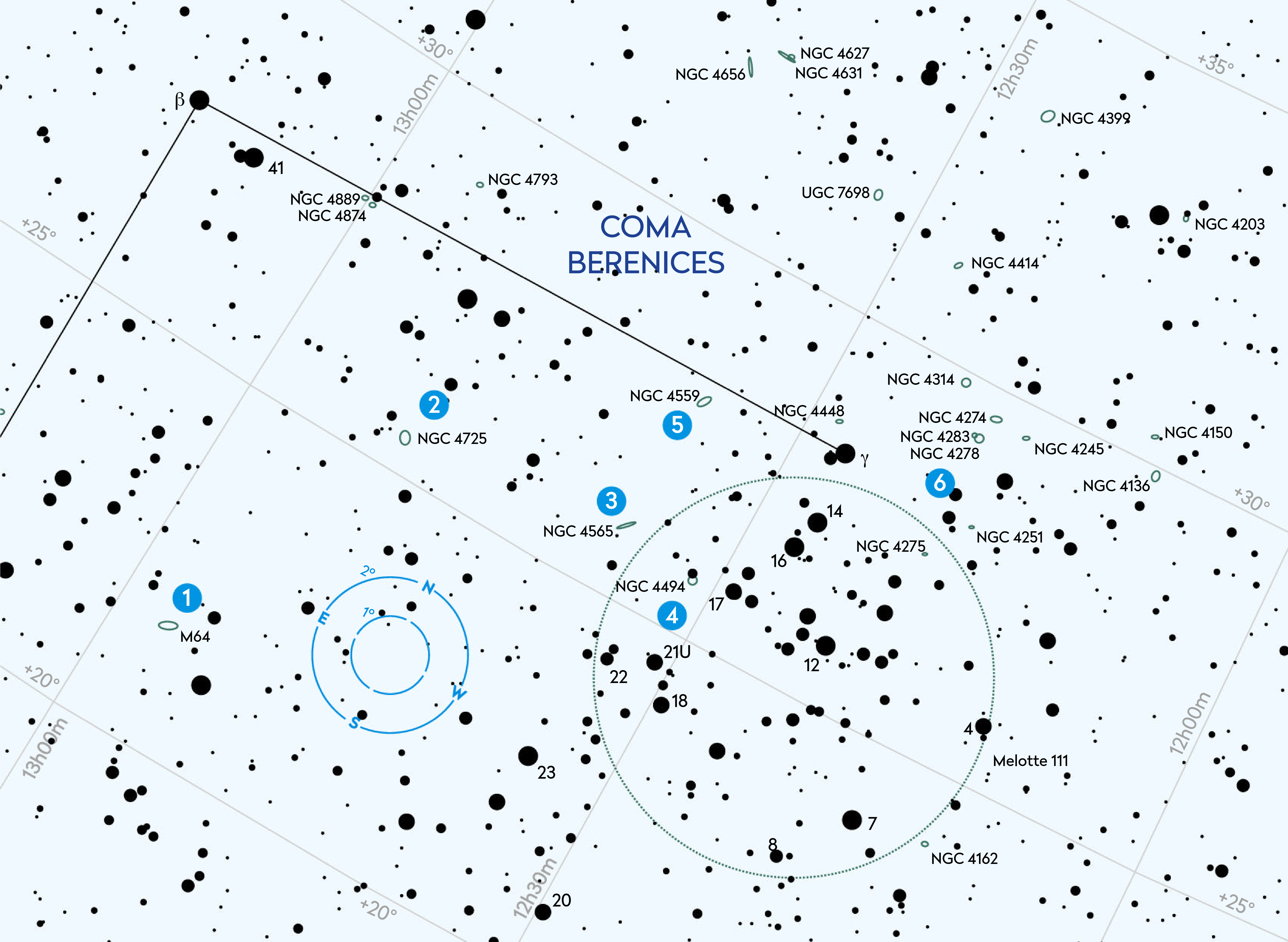
6 NGC 4278

We return north for elliptical galaxy NGC 4278. Return to Gamma Comae Berenices and head 1.6° west to locate mag. +6.4, 9 Comae Berenices. Next, manoeuvre 1.1° north and you'll be in the right vicinity. NGC 4278 shines with an integrated mag. +10.2 and (like NGC 4494) is classed as an E1-2 type elliptical. There are several other galaxies here too, with 12th magnitude NGC 4283 located 3.5 arcminutes to the north-northeast. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. **See page 5 for instructions.**


COMA BERENICES
β
γ
41
NGC 4889
NGC 4874
NGC 4793
NGC 4656
NGC 4627
NGC 4631
NGC 4399
UGC 7698
NGC 4203
NGC 4414
NGC 4314
NGC 4274
NGC 4283
NGC 4278
NGC 4245
NGC 4150
NGC 4136
NGC 4251
NGC 4275
NGC 4448
NGC 4559
NGC 4725
NGC 4565
NGC 4494
NGC 4162
Melotte 111
M64
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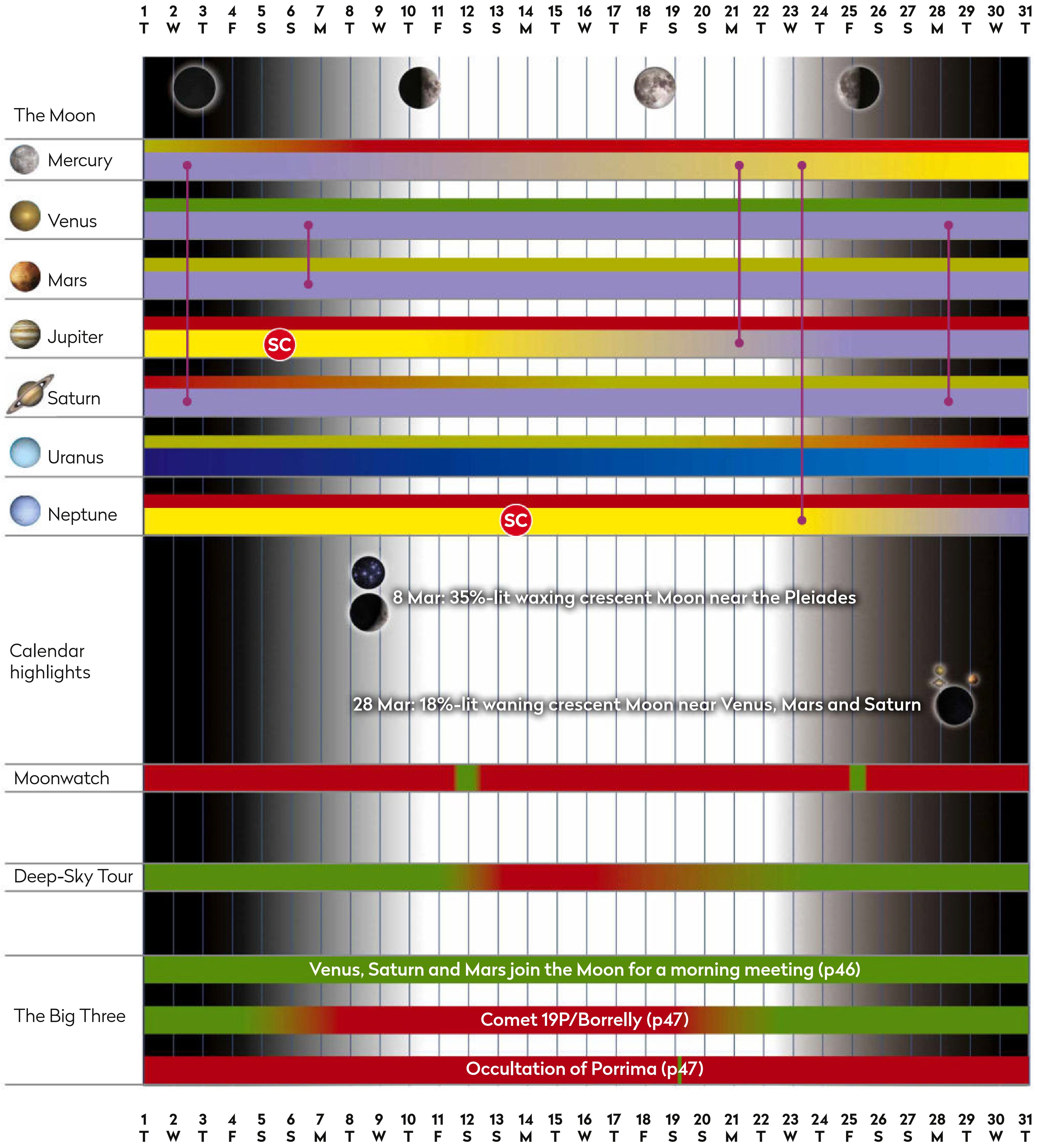
12h00m

AT A GLANCE How the Sky Guide events will appear in March



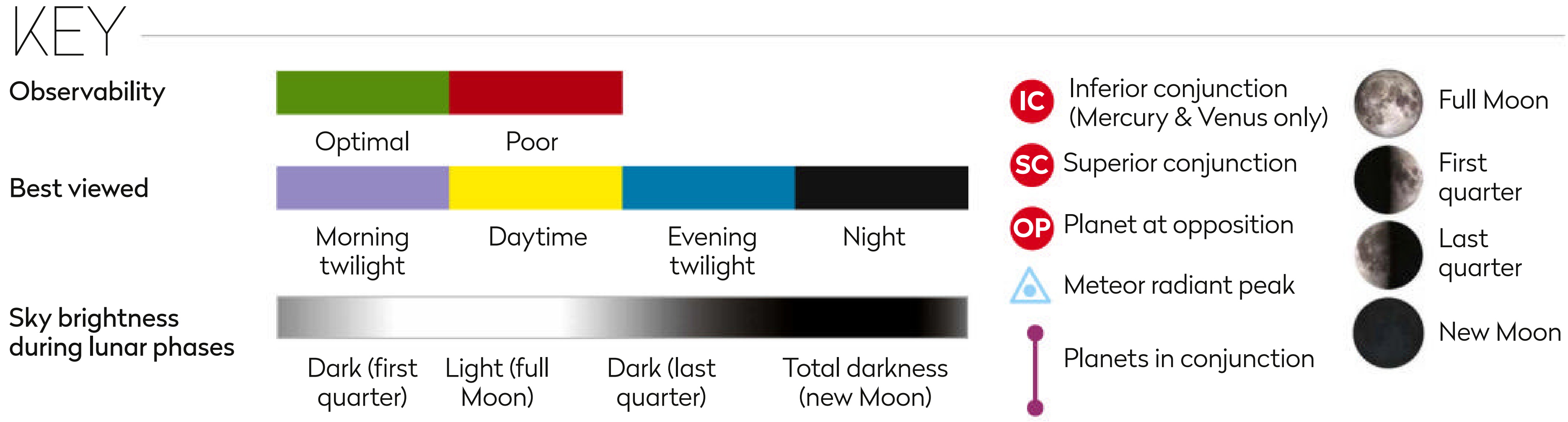


CHART BY PETE LAWRENCE

Learning how to read the weather will pay dividends for your observing time

THOMASLENNE/ISTOCK/GETTY IMAGES

CLEAR SKIES AHEAD?

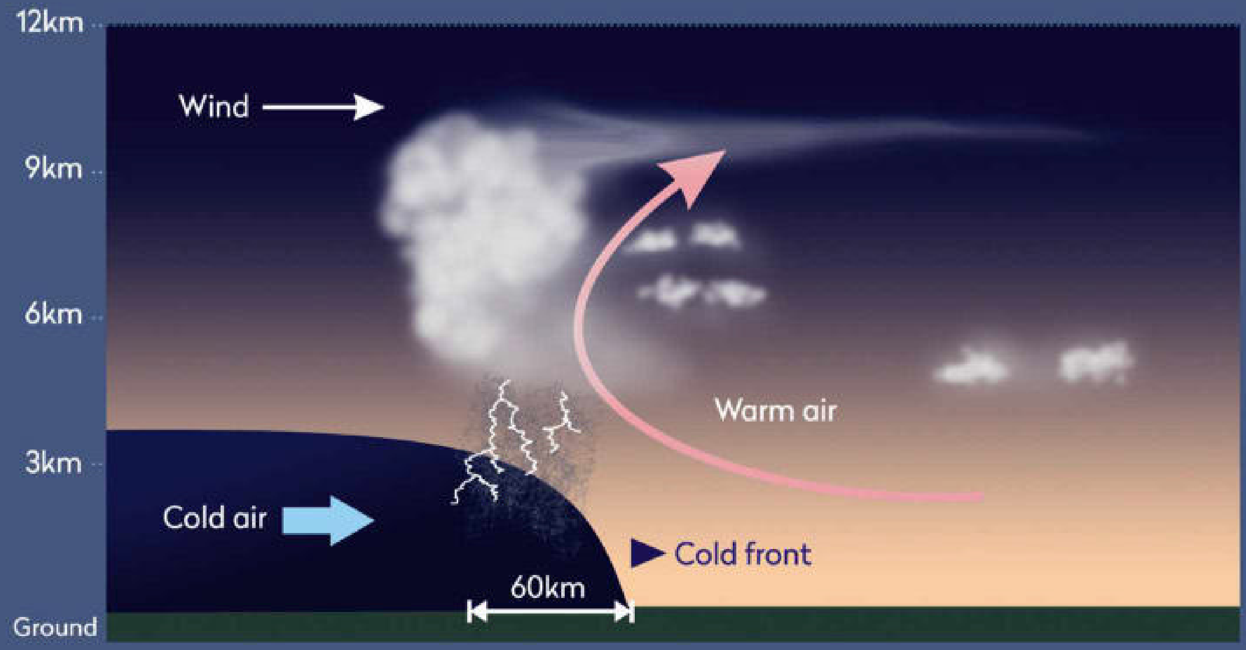
Weather forecasting for astronomers

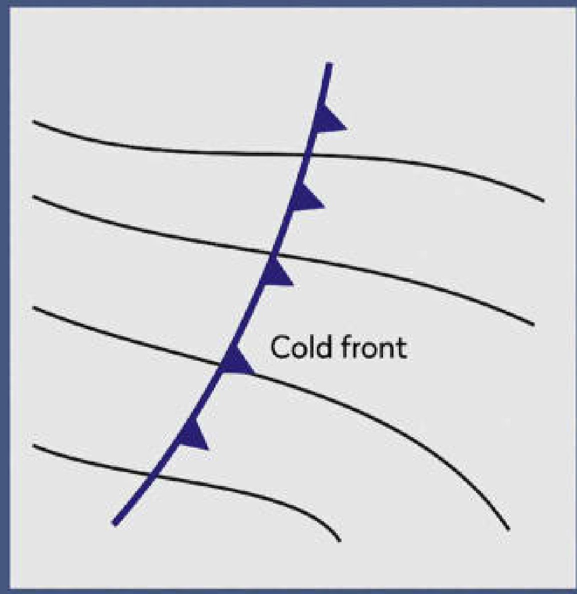
Pete Lawrence shows you how to assess the changeable atmosphere to tell how it will affect your stargazing

Earth's atmosphere is very important and without it we obviously couldn't survive. However, observing objects through it can be challenging. The impact of weather on astronomical observing from a country prone to damp conditions such as the UK is significant and although you can't remove its effects, there are things you can do to lessen its impact. Weather forecasting, estimation of sky quality and general sky watching can help you in your quest to see beyond our world.

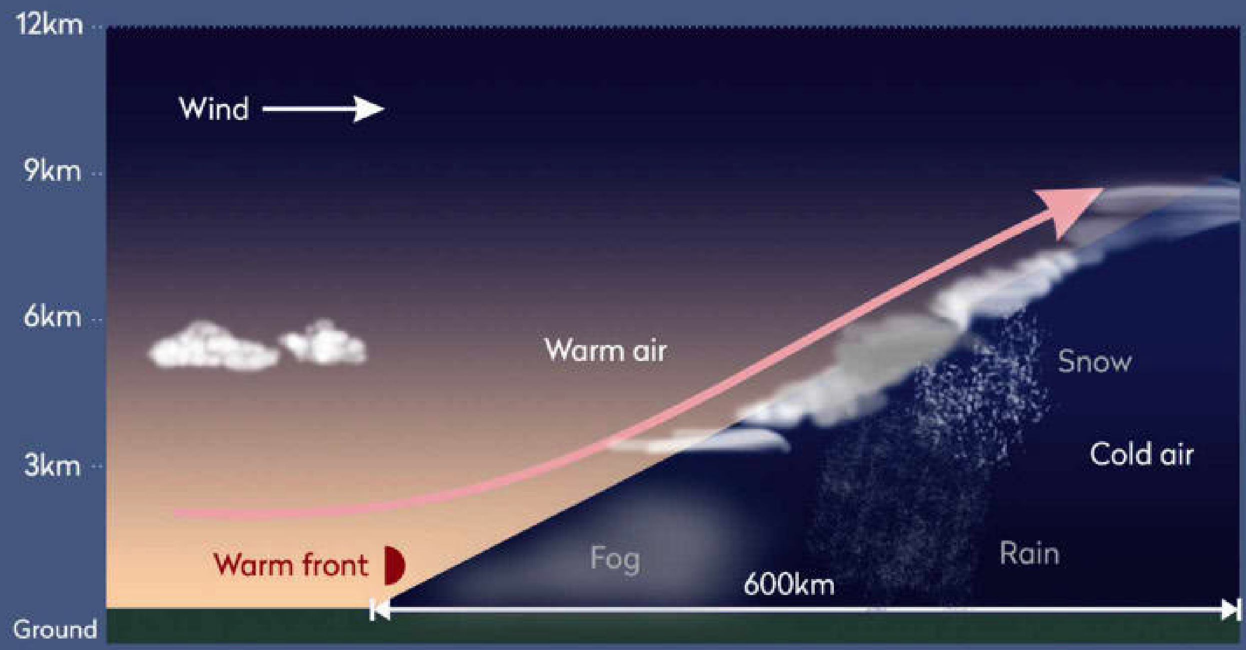
The atmosphere is remarkably changeable and can go from a crystal clear, rock-steady state to an extremely wobbly, hazy or opaque state in a very short time. Observing over many years produces a personal connection with your local weather and you'll find you can make your own assessment as to how it is likely to affect your viewing. More often than not, you'll have to develop techniques to grab views when available and getting good at this can mean the difference between a challenging observing session and spectacular success.

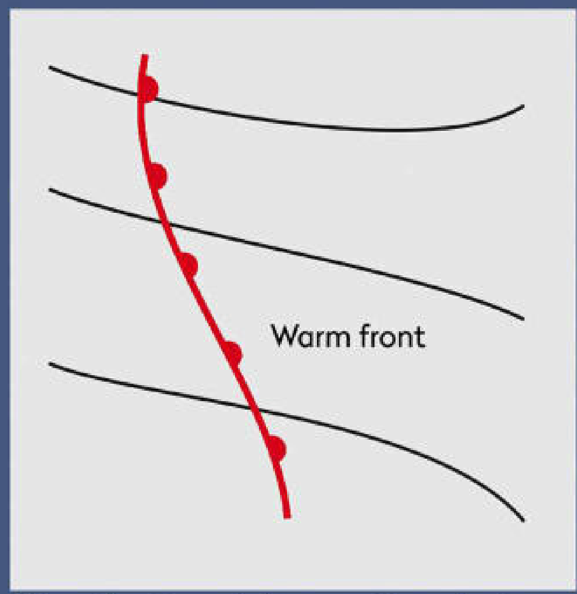
Pete Lawrence is an experienced astronomer and a co-host of *The Sky at Night*





Cold front symbol on weather chart





Warm front symbol on weather chart

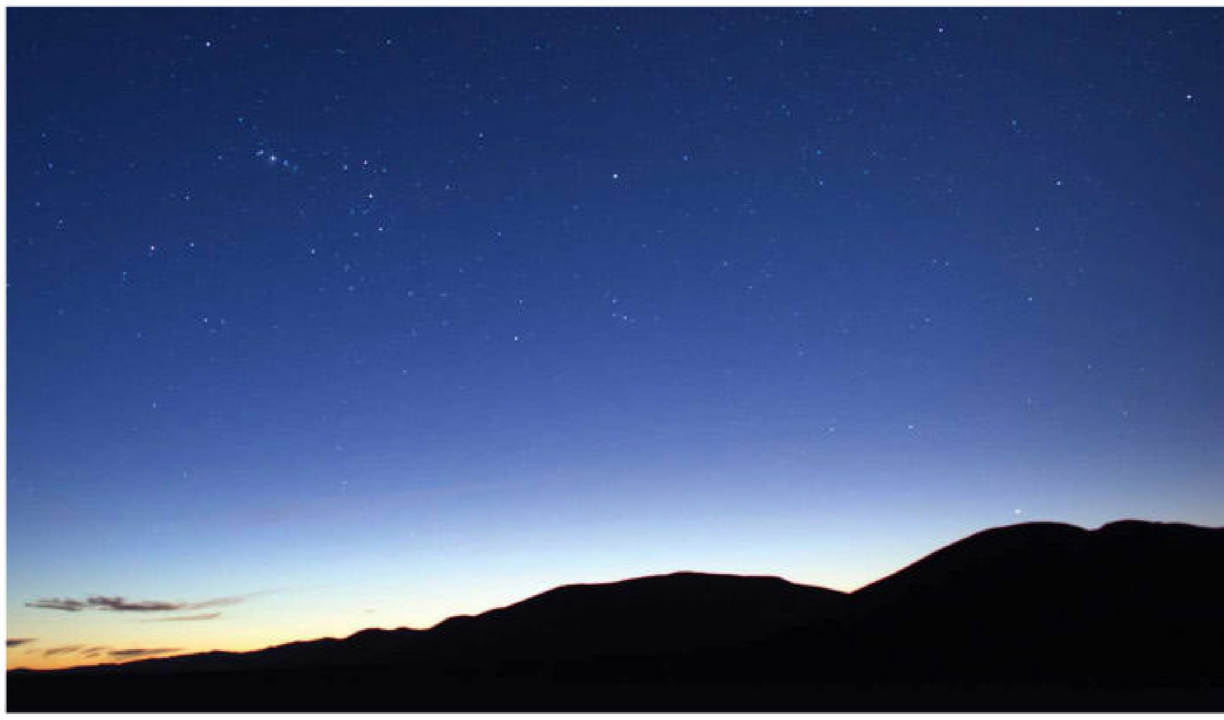
▲ **Cloudy conditions accompany oncoming frontal systems; if air ahead of the front has reached equilibrium it may provide stable seeing**

Sky transparency

Unless you're extremely unlucky or are just starting out, you have probably experienced clear skies at one time or another. They can be breathtaking and highly addictive, refuelling your desire to be out under the stars. However, spectacularly clear skies are typically few and far between. Fully opaque skies, on the other hand, are all too common from wet countries such as the UK. Yet there is a huge diversity of weather that sits in between these extreme states, and although some of the intermediate conditions are not perfect for astronomy, you can still learn how to make the most of those nights when observing is a bit trickier.

If the sky is clear, the degree of clarity is quantified by a value called transparency. This may, for example, be recorded as a number ranging from 0 (opaque cloud) to 7 (perfect). It should be noted that transparency is not an observational indicator of cloudiness, but is intended to indicate the opacity of the atmosphere; in other words, how hazy it appears and how easily objects can be seen through it. Hazy skies can occur due to excessive moisture or because there's dust in the atmosphere. Typically, hazy skies are a combination of both. Pollen is another contributor to poor transparency and it's important to realise that this introduces an annual cycle that affects the quality of your sky. After heavy rain the atmosphere often exhibits good transparency due to the fact that much of the dust contained within it has been washed out. So even if a downpour stops one night's observing, it means you could be due for a clear sky the next day.

Good transparency will give the best views, objects appearing brightest and faint wispy detail around nebulae and galaxies will be easier to detect. As the sky becomes less transparent, such detail is gradually lost. Although less affected than diffuse deep-sky objects, the view of a bright planet will still be degraded by poor transparency; contrast is diminished and small features become harder to discern and image.



▲ **A crystal clear evening twilight sky can lead to a breathtaking night of astronomy ahead**

PETE LAWRENCE X 3, DENNIS H. MILLER/ISTOCK/GETTY IMAGES

Transparency and how to record it

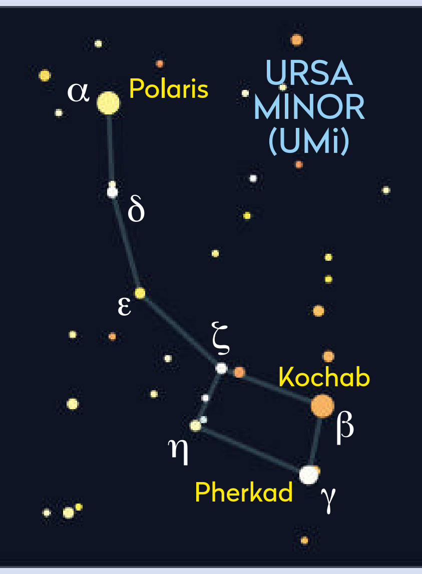
Learning to measure transparency will help you compare sky clarity under different conditions and locations, from dark-sky areas to cities

Measurement of transparency can be subjective and there are many different scales that attempt to provide standardisation. For example, a popular numeric system used by the American Association of Amateur Astronomers uses an eight-point scale (see right) ranging from 0, indicating that it's completely cloudy, through to 7, which indicates extremely clear skies.

Another popular method is to record the faintest star visible in your sky, typically one that's overhead. The star's magnitude is noted as a NELM (naked-eye limiting magnitude) value. This is a less subjective method of recording transparency, especially as the recorder typically has no idea what the actual magnitude of the selected star is until after it has been noted and looked up.

Transparency varies with location. The faintest stars visible from a dark site may not typically be seen from a town or city.

0 Cloudy and unobservable
1 Mostly cloudy: opportunities limited
2 Partly cloudy/heavy haze; 1–2 UMi stars visible
3 Clear but hazy; 3–4 UMi stars visible
4 Clear with only slight haze present; 4–5 UMi stars visible
5 Clear, no clouds; Milky Way visible using averted vision; 6 UMi stars visible
6 Very clear, Milky Way is easy; a +6.0 naked-eye limiting magnitude (NELM) from a dark site
7 Extremely clear; Milky Way easily seen when up; a NELM better than +6.0 from a dark site



▲ The scale of transparency used by the American Association of Astronomers

Heavily built-up locations tend to have more dust and smoke particles in the atmosphere. Excessive lighting throws light up into the sky and this will ultimately illuminate these particles. The result is a bit like applying an opaque filter across the night sky. It is noticeable when the sky leading up to sunset appears clear; it's as the day transitions into night that poor transparency becomes apparent.

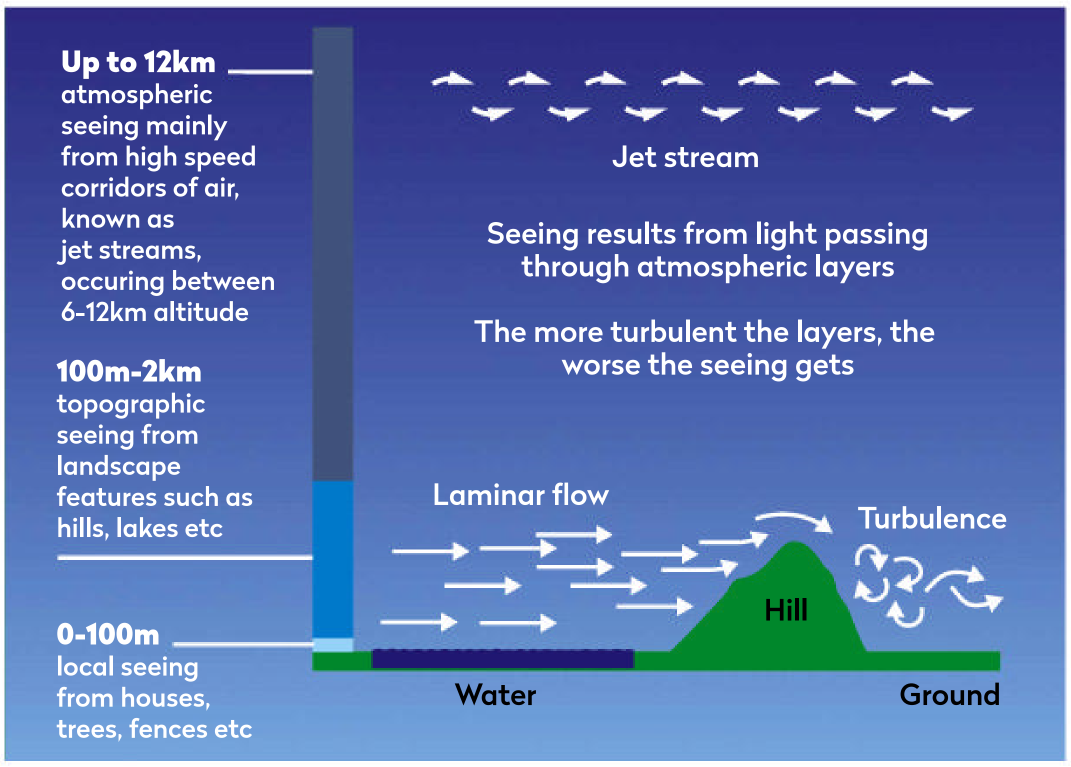
Astronomical seeing

The atmosphere is not a fixed optical medium. Blobs of air of different temperatures and densities cause the light from distant objects to micro-refract. This causes small deviations in the light path and, at relatively high frequencies, causes objects to appear distorted and fuzzy. The degree of distortion is quantified under the collective term 'seeing'.

Seeing is complicated and varies greatly with location. In essence its effects occur in three layers of the atmosphere. At high altitude, a fast-moving corridor of air known as the jet stream can cause high-frequency jitters that seriously degrade the view. The effect is often likened to trying to read newspaper print placed at the bottom of a fast-moving stream of water!

At the mid-level, seeing effects come from the movement of air above and around large-scale topographic features. These could be hills or mountains, valleys or depressions, or large expanses of water. The latter can produce what's called 'laminar flow', which settles the mid-layer effects quite dramatically. Being downwind of a hill or ridge, you will experience turbulence. Similarly, heat from a town or city will create air instability. If you are downwind of a heat source like this, again you will experience turbulence.

At the bottom layer, the effects are caused by local features such as immediately adjacent houses, trees and fences. Large areas of tarmac surface will warm up during the day and release heat during the night. This may cause significant seeing issues too, depending on wind direction, so it's best to avoid these and set up in grassier areas if possible. During the winter, home heating combined with poor insulation may create disturbed seeing due to hot domestic air mixing with cold air. ►



▲ Seeing results from the combined effects of different atmospheric layers

Seeing and how to record it

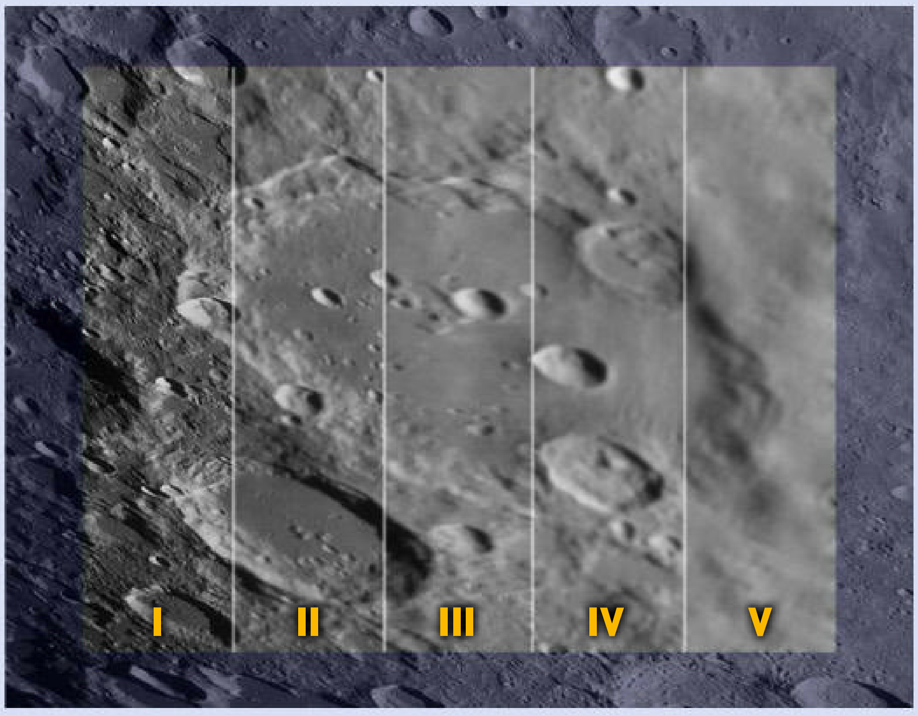
Using scales to assess the atmospheric seeing will enable you to predict how much it will affect your observing

ANTONIADI SEEING SCALE

Best

- **I** Perfect, no distortions
- **II** Steady periods lasting for several seconds interrupted by minor rippling
- **III** Reasonably steady but with frequent large ripples which blur the image
- **IV** Constant undulations resulting in a generally poor view
- **V** Extremely unstable, very difficult to see any detail at all

Worst



▲ The Antoniadi five-point scale is used to describe seeing conditions, but note that the value may vary throughout a night

The two main seeing scales are the Antoniadi scale (above) and the Pickering scale (below). Others exist but these are the two most commonly used by amateur astronomers. The Antoniadi scale has five values, indicated by Roman numerals, I being the steadiest, V being very unstable.

From the UK, Antoniadi seeing types III and IV are most common, but periods of II do happen, typically at times when high pressure dominates the weather. Antoniadi I conditions are rare, occurring perhaps only on a couple of nights throughout the year. It is important to understand that seeing may vary considerably over the course of a single night. Initially, poor seeing conditions may give way to much steadier conditions over the course of a night or vice versa.

The Pickering scale was devised by William H Pickering of Harvard College Observatory. It's based on the views through a 5-inch (120mm) refractor and is a 10-point scale. Just to make things complicated, the Pickering scale denotes the worst seeing at the lower end of the scale and best at the upper end, which is the opposite of the Antoniadi scale. As a rough equivalence to the Antoniadi scale, Pickering 1–2 is considered very bad seeing, 3–4 is poor seeing, 5–6 moderate, 7–8 good and 9–10 excellent seeing.

Seeing is something that gets easier to assess over time as you gain experience, simply because you need to actually see the effects of each level of stability before you can confidently identify them. Perfect seeing is really something to behold and allows a view which is hard to forget.

As mentioned in the main text, seeing generally occurs in three discrete layers in the atmosphere. The lower and mid layers are greatly affected by wind and it's important to keep a note of the wind direction when you get good seeing. High level seeing can be predicted to a degree, by the location of the jet stream. It is well worth using a forecast service such as NetWeather (**www.netweather.tv/charts-and-data/jetstream**), which is very useful for this purpose.

PICKERING SEEING SCALE

1 Very poor: Star appears 2x the diameter of the third diffraction ring; star diameter is 13 arcseconds

3 Very poor: Star occasionally 2x the diameter of the third diffraction ring

3 Poor to very poor: Star about the same size as the third diffraction ring; star diameter is 6.7 arcseconds

4 Poor: Central Airy diffraction disc often seen along with arcs of surrounding diffraction rings

5 Fair: Airy disc always present, diffraction ring arcs often seen on brighter stars

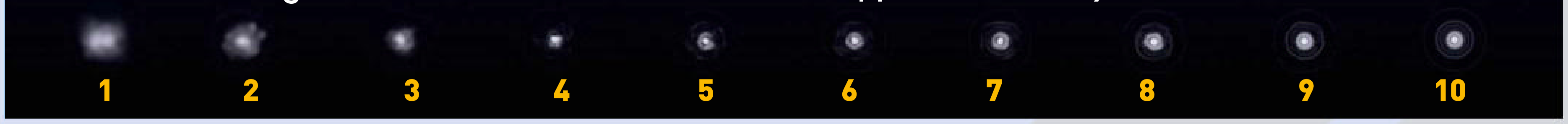
6 Fair to good: Airy disc always present, short diffraction arcs constantly seen

7 Good: Airy disc sharp and well defined, long diffraction arcs or complete circles seen

8 Good to excellent: Airy disc well defined, long diffraction arcs/circles seen but in motion

9 Excellent: Inner diffraction ring static, outer rings occasionally static

10 Excellent/perfect: Entire star diffraction pattern appears stationary



▲ The Pickering scale shows the effects of atmospheric turbulence on a star image, from 1 = Very poor, to 10 = Excellent/perfect

ALL CHARTS AND PICTURES: PETE LAWRENCE

Forecasting strategies

▲ Energy from the Sun greatly influences seeing conditions throughout the day

There are many ways of getting predictions for astronomical weather and there isn't one single method that will always give accurate results. If things don't pan out as predicted, the next best option is to adapt your strategy to what you've been offered.

For high-resolution Solar System work, good seeing is critical. At high altitude within the atmosphere, this is at the mercy of the jet stream. Services such as NetWeather (**www.netweather.tv**) provide constantly updated jet stream forecasts that will help you plan your observing. If the jet stream is raging over your location, chances are the seeing will be poor.

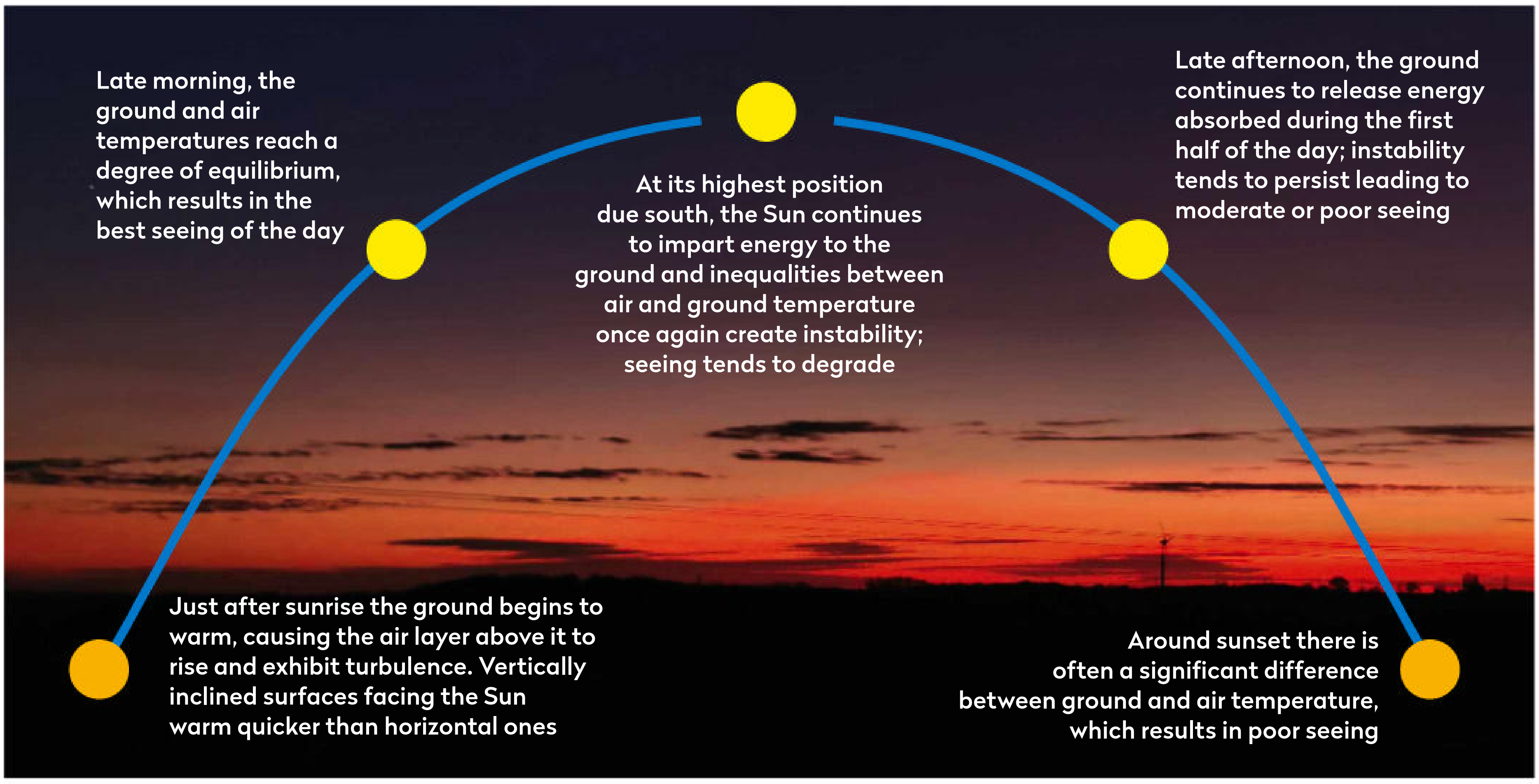
If you're a solar observer, the Sun introduces its own special considerations. As the Sun rises, its light bathes the ground, causing it to warm up. The heat released causes thermal instability, which stabilises as the ground and air temperatures equalise. Towards the end of the day, energy absorbed by the ground is released as heat which destabilises the view, so picking the optimal time for solar observing requires keeping a record of the best time of day to begin.

Sometimes location just works against you. If you live to the east of a hill range, with the prevailing wind coming from the west, your location to the lee, or sheltered, side of the hills will likely promote instability and this will create poor mid-level seeing. You might want to find a new observing site on the other side of the hills, or keep watch for days when the wind is coming from a more suitable direction.

Looking at synoptic charts showing pressure, fronts and wind speeds will give you an idea of the weather and airflow over your observing site. Low pressure isn't ideal as it tends to introduce clouds and disturbed, windy conditions. High pressure can produce clear and stable conditions, but these are not hard and fast rules and exceptions do happen. High pressure with fog can lead to frustration, although observing a planet or the Moon at high altitude can still give stable views.

Cloud forecasts are difficult to get right, especially at night. usee these as a guide rather than an accurate prediction of what you're going to get. Monitoring infrared satellite images will give you a much better idea as to the viability of such forecasts and enable you to take advantage of unexpected cloud gaps. ▸

▼ The solar-seeing cycle timing tends to be unique for each location



Reading the weather

If you're an active observer, it's surprising how your senses become tuned to various conditions that may affect your view. For example, you soon learn that the aftermath of an active front may leave you with good transparency, but poor seeing as the atmosphere tries to regain a degree of equilibrium.

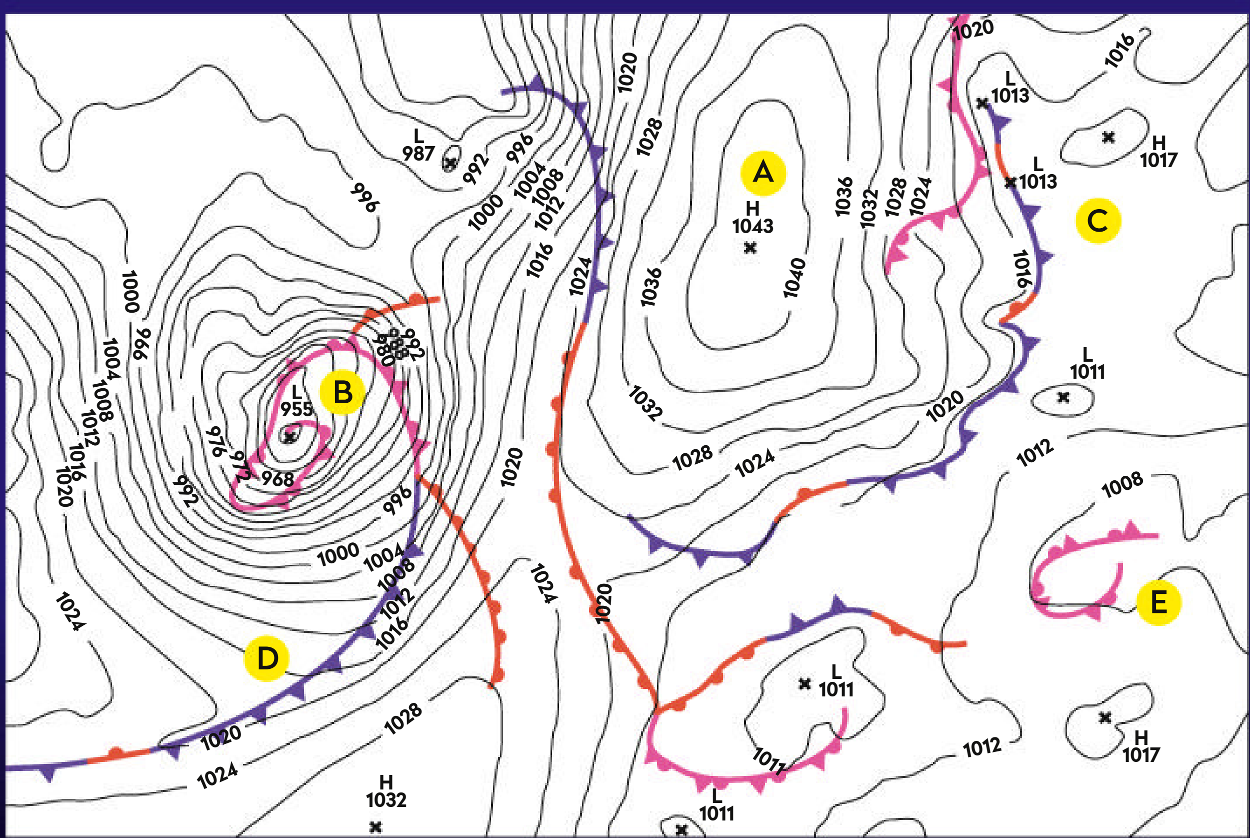
Dry, cold conditions tend to be stable too, but add moisture into the mix and things can turn unsettled. A cloudless high-pressure system sitting over the UK will bring observational joy to many, especially high-resolution Solar System imagers who require steady seeing for the best results.

If the skies aren't perfectly clear and you're relying on cloud gaps, a free satellite imagery service such as Sat24 (**bit.ly/3HcRSp6**) can be invaluable. However, bear in mind that the sky appears like a flattened dome above your head and cloud gaps near the horizon will appear foreshortened. A large circular gap will appear low down as a narrow ellipse with barely any sky visible through it. As it approaches your overhead position, you'll experience the full glory of its clear sky area, but geometry has a cruel twist in store. As the gap in the clouds passes overhead, the distance between you and the gap minimises. This means the apparent speed of the gap across the sky reaches a maximum value. Although the area will be best presented, you'll have it for the shortest time!

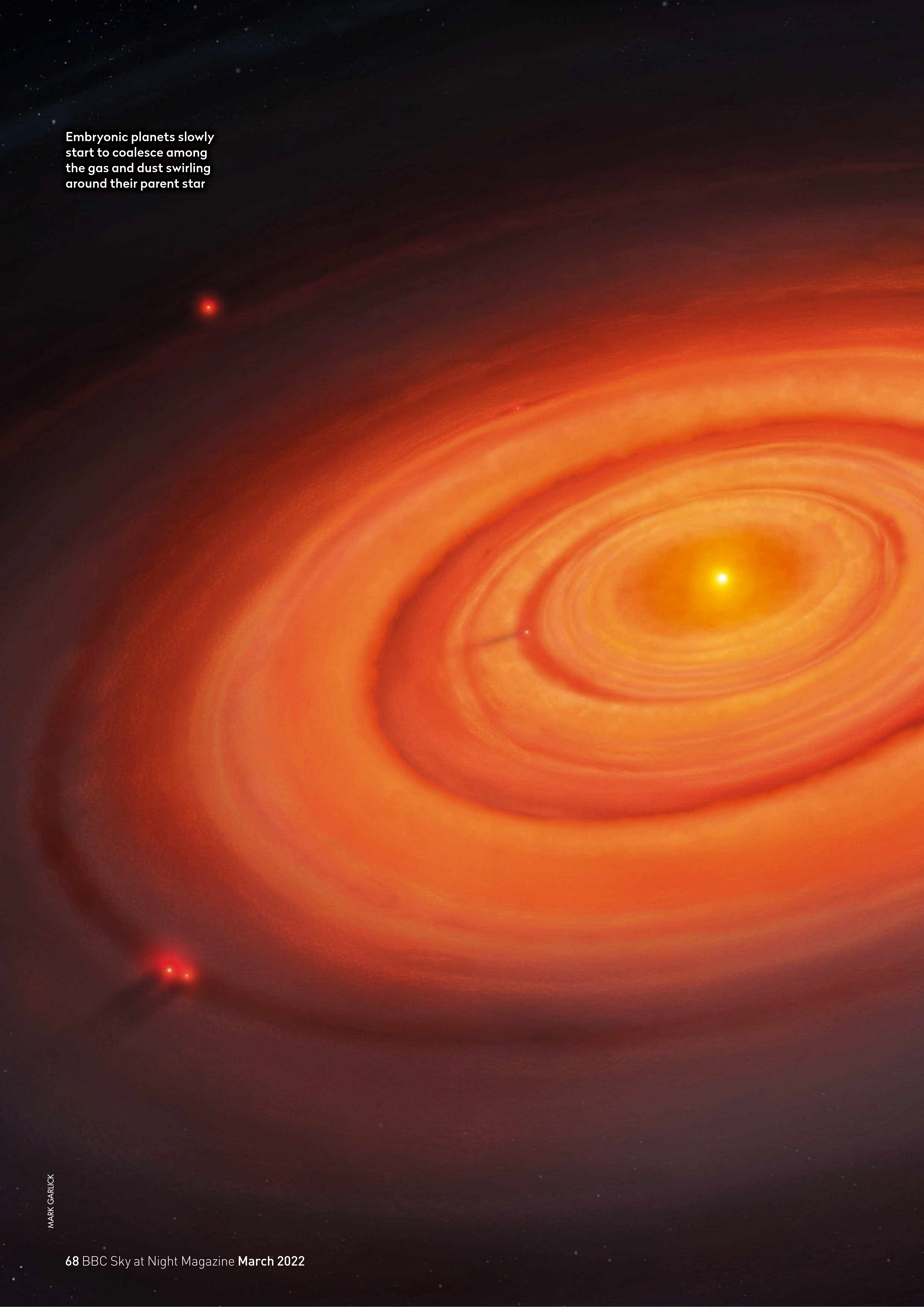
▲ If there are gaps in the clouds, these may present you with a wonderful view, but time will be limited if the gap is passing overhead

KSCHULZE/ISTOCK/GETTY IMAGES, CHART BY PETE LAWRENCE

▼ A synoptic weather chart gives clues to seeing conditions



- **A** High pressure can bring stable conditions resulting in good seeing
- **B** Low pressure surrounded by tightly packed isobars (pressure contours) will typically contain lots of cloud and strong gusty winds which will result in unstable seeing
- **C** Ahead of an advancing cold front, stable, warm air may offer good seeing
- **D** Warm air displaced up by a cold front will typically be followed by unstable seeing conditions
- **E** An occluded front occurs when warm air is trapped above cold air after the advancement of a cold front. Warm, cold and occluded fronts are associated with cloudy conditions as well as thermal instability



Embryonic planets slowly start to coalesce among the gas and dust swirling around their parent star

MARK GARLICK

Growing Worlds

The journey from dust cloud to planet has long been shrouded in mystery, but astronomers are now getting a clear view of how young exoplanets grow, says **Ezzy Pearson**

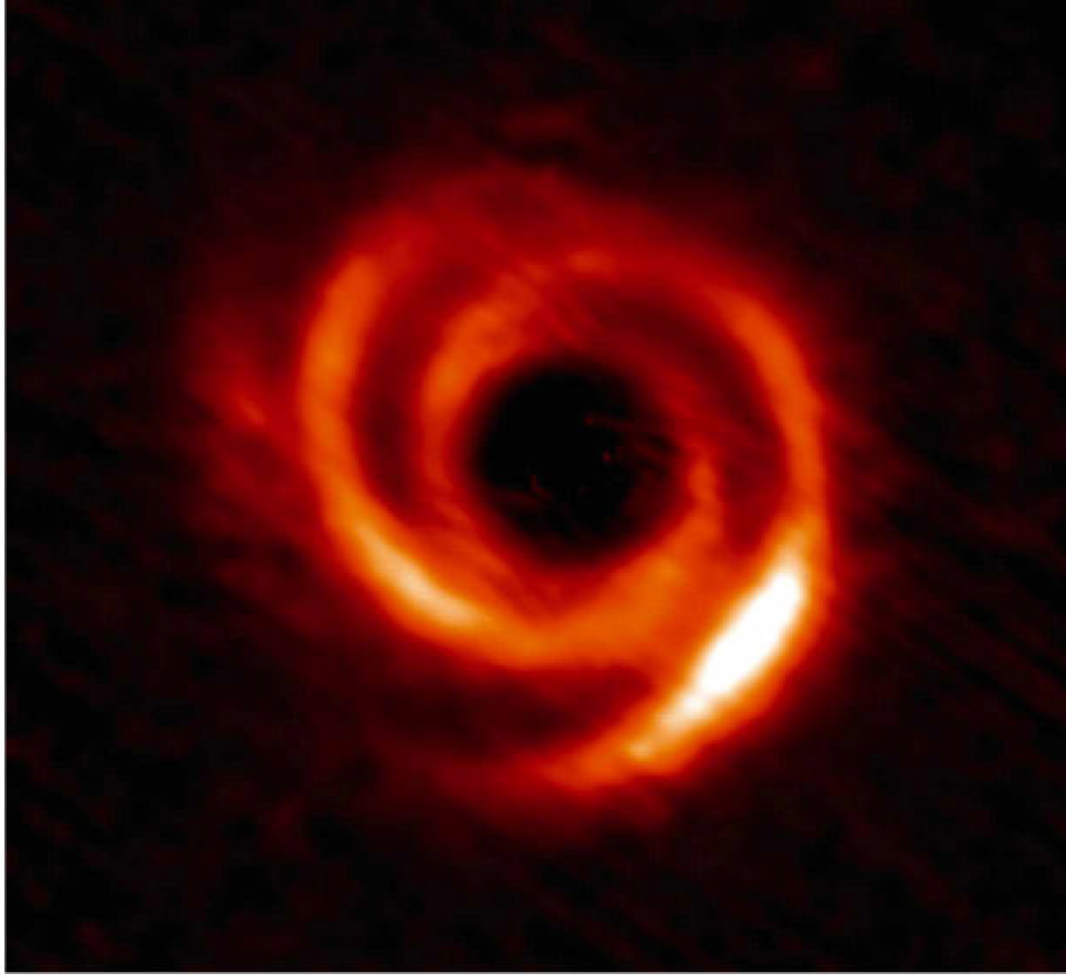
An explosion of exoplanet discoveries has swept through astronomy in the last 30 years. Prior to 1989, humanity only knew of the planets in our own Solar System, but today the number of confirmed extrasolar planets is nearing 5,000 thanks to space telescopes like Kepler and the Transiting Exoplanet Survey Satellite (TESS) scanning the stars for other worlds. The more exoplanets that are found, the greater the diversity of worlds we know about – from worlds meeting their ends by tumbling into stars, to infant planets just beginning to form.

The study of these young planets and the circumstellar discs of dust and gas from which they emerge has blossomed as a field in recent years. Observatories such as the Atacama Large Millimeter/submillimeter Array (ALMA) have allowed astronomers such as Jaehan Bae from the University of Florida to examine the discs in more detail than ever before.

"I'm interested in how planets form – not just extrasolar planets, but those in our Solar System too," says Bae. "Historically, we've used theories, equations and simulations because observing planets while they're forming is extremely hard."

Thanks to ALMA it's now possible – but still challenging – to view these planet-forming discs. ▸

ILLUSTRATION



▲ Left: Astronomer Jaehan Bae creates a simulation of a planetary disc, in order to see what structure is created by the planet – in the lower section of the simulation

Right: He can then make a comparison with a real observation of the young star SAO 206462 and its circumstellar disc

JAEHAN BAE, J. OLMSTED (STSCI)

▶ First though, you have to find one. Although stars like the Sun live for around 10 billion years, their discs last for only five to 10 million years – 0.1 per cent of the star's lifespan. The best places to spot them are in the regions around stellar nurseries, where new stars are forming. Unfortunately, these are dust-rich environments and there aren't any close to Earth, so observing the planet-forming discs clearly is difficult.

Superficial details

Nevertheless, many planet-forming discs have been found, raising the next challenge: to understand what's happening in them. Prior to their first observations, astronomers thought this might be a tricky prospect as they expected the discs to be smooth, featureless and, frankly, rather boring.

"But it turns out they're not," says Bae. "We see plenty of different structures: rings and gaps, spirals and vortices – all sorts of different things that suggest there might be a lot of planets."

Even though ALMA can't observe the inner 10 astronomical units of any discs it sees clearly (1 AU is the distance between Earth and the Sun), there's no shortage of features to spot in their outer regions. Some of these are easy to explain. As they form, planets often clear out great swathes of dust, leaving dark lanes and sharp edges to betray their presence. Sometimes it's even possible to directly image nascent planets as bright points of light. In 2021, observations of the planet PDS 70c revealed that it had surrounded itself with its own disc, from which it could one day form a family of moons.

But not all features are clear, particularly in younger discs where the planets are still forming. Here, all there is to go on are the patterns in the dust, created by the movements of hidden planets. To connect

How to grow a gas giant

Watching gas planets during their youth is key to understanding how they're born

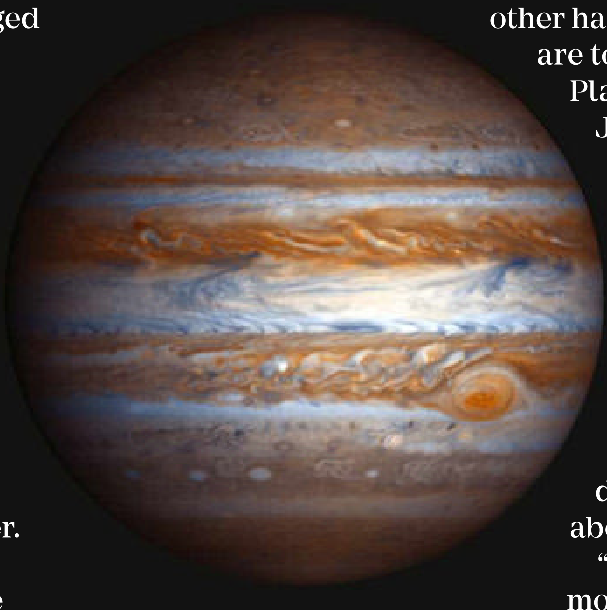
How clouds of dust transform into fully fledged gas giants is one of the key questions for astronomers researching young exoplanets.

"There are two competing theories," says Jaehan Bae of the University of Florida. "The first is the 'bottom-up' process, where you initially form a small, rocky core that becomes more massive. It starts to collect gas from the disc and forms a gas giant like Jupiter. Then there's the 'top-down' theory, where the disc becomes unstable due to its own gravity and collapses to form a planet. We don't know which is right, even for Jupiter."

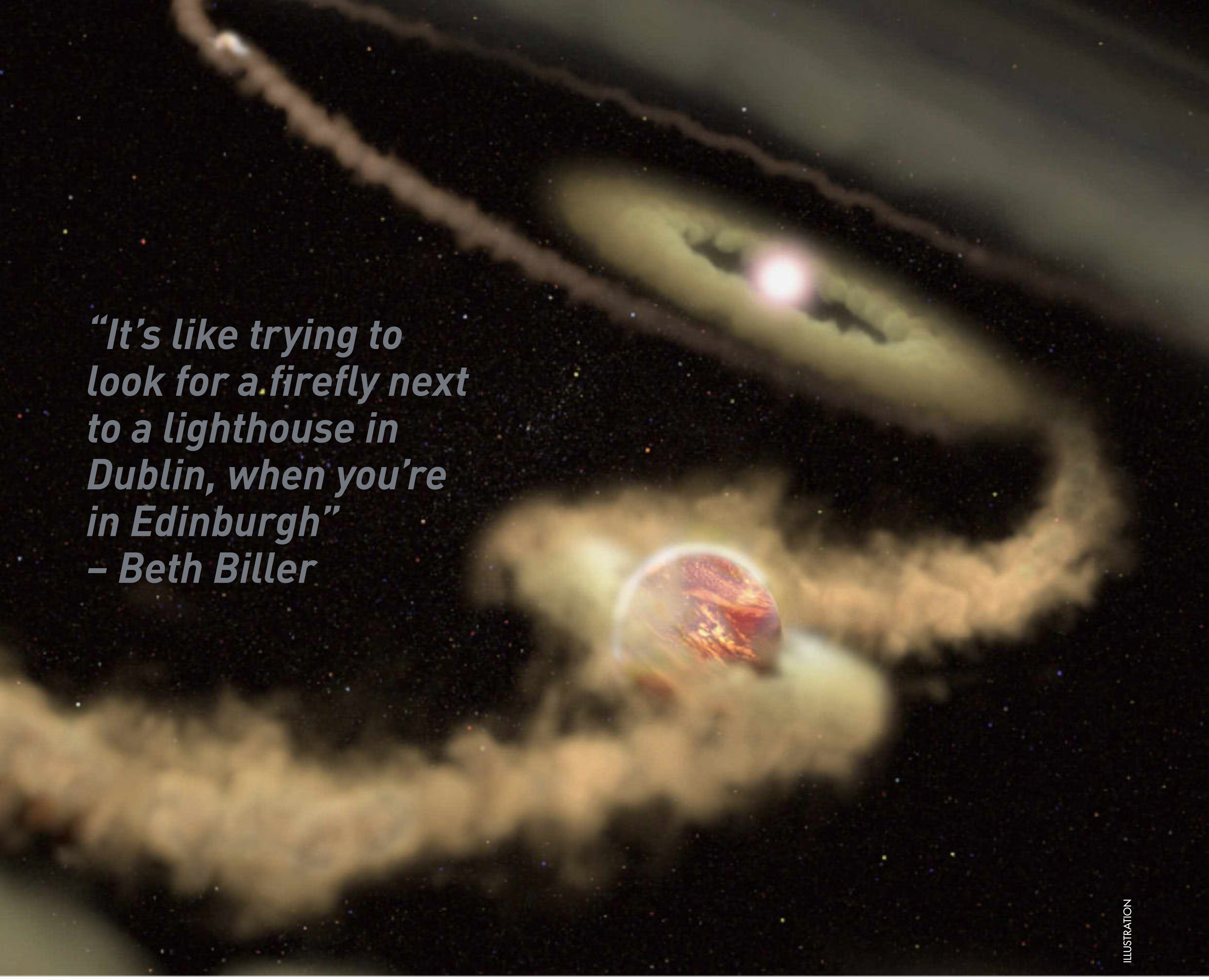
Both of these ideas have problems, however. In the 'bottom-up' model, regions of the disc far from the star are too cold for planets like Neptune to form within the 10 million-year window before the disc disappears. On the other hand, the 'top-down' model forms planets that are too massive to remain in stable orbits. Planets that are many times the mass of Jupiter fall into their stars far too readily.

To delve deeper into the mystery, astronomers observe young planets while they're forming. Planets formed via the 'top-down' process are expected to be warmer than their 'bottom-up' counterparts, so mapping out the mass and temperature of forming planets could yield vital clues. Meanwhile, tracking how planets are distributed in the disc at different points in their lives will reveal more about their patterns of migration.

"It's not a yes/no question," Bae says. "Both models can form giant planets, but they may work in different regions of the disc, or under different conditions."



▲ Precisely how gas giants like Jupiter form is still up for debate



“It’s like trying to look for a firefly next to a lighthouse in Dublin, when you’re in Edinburgh” – Beth Biller

▲ An artist’s impression of two gas giants orbiting the young star PDS 70, shows them accreting material from a surrounding disc

these obvious features with the physical process that cause them, Bae is creating computer simulations of the discs. By comparing these with their real-life counterparts, he can begin to link what we see with the physical processes they indicate. His studies will help answer one of the key questions in this field: when do planets begin to form?

“Astronomers had thought planet formation happens a few million years after the star has formed,” says Bae. “But we see these substructures in younger and younger circumstellar discs. We’ve seen some that are very young, less than a million years old, which suggests planet formation could have already happened.”

Young planets, old stars

Looking back from the other end of the timescale, however, makes the process far easier to work out.

“In order to form a planet like Jupiter,” says Bae, “We need gas, which means the planet has to form before the circumstellar disc disappears after around 10 million years.”

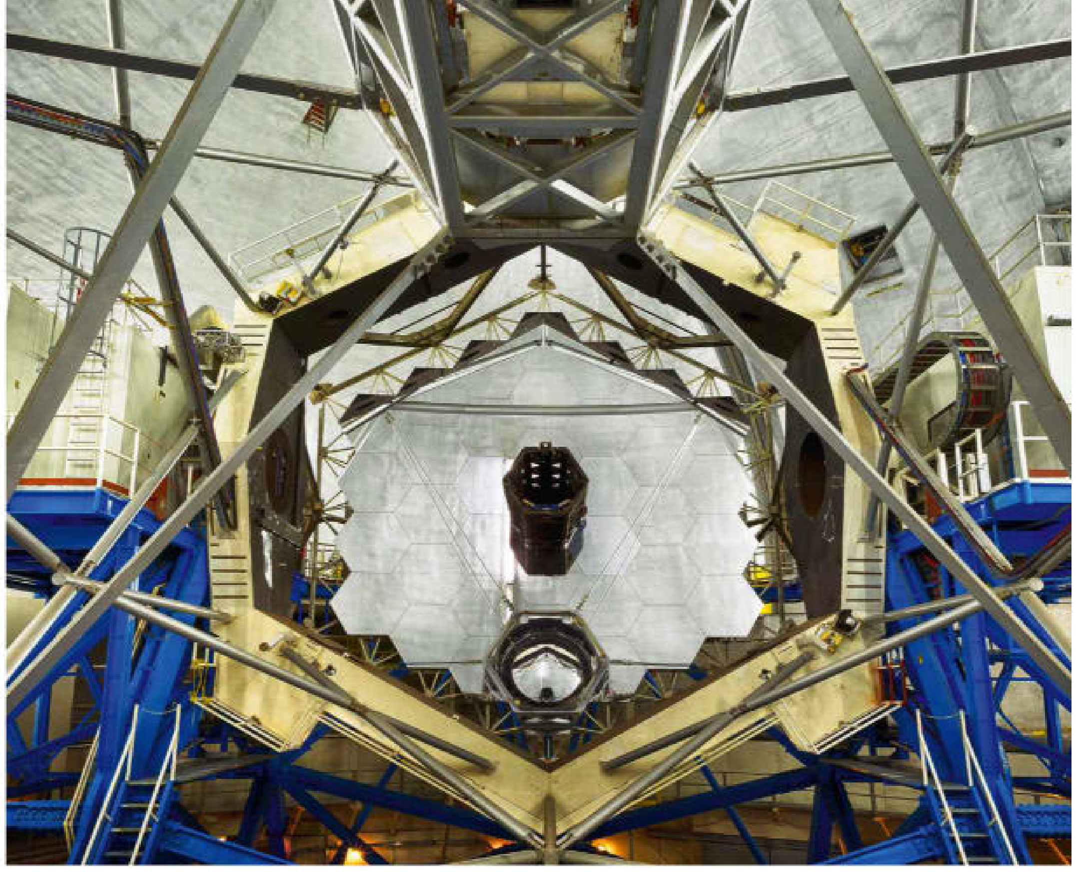
After this period, with no dusty disc to reveal what’s happening, astronomers must rely on other forms of observation. Fortunately, young exoplanets are one of the only types of planet that astronomers such as Professsor Beth Biller from the University of Edinburgh are able to capture directly the light from, in the form of infrared radiation.

“We’re looking at stars [that are] about five to a hundred million years old. Young planets, those closer to formation, are hotter [than stars that old]: at their cloud tops they’re about the temperature of a candle flame,” says Biller. “If you look in the infrared you can see them glowing.”

While stars also emit infrared light, they’re dimmer at these wavelengths than in the visible part of the spectrum, so the star isn’t overwhelmingly bright compared to the planet. But as the star is still 100,000 times brighter than a typical Jupiter-sized world, it’s still quite a challenge. “It’s like trying to look for a firefly next to a lighthouse in Dublin, when you’re in Edinburgh,” says Biller.

To combat this brightness, astronomers use a coronagraph on their telescopes – a filter that sits in front of the star, blocking out its glare and allowing them to see what’s going on.

“You need to be able to resolve something to within half an arcsecond,” says Biller. “Some telescopes such as Hubble have coronagraphs that block out the inner arcsecond – the entire real estate area in which you’d be looking for planets.” ▸



▲ The mirrors in both of the telescopes at the Keck Observatory feature adaptive optics to counteract the distortion caused by air currents

▸ Some ground-based observatories, such as the Very Large Telescope (VLT) in Chile and the Keck Telescopes in Hawaii, have been updated with modern, small-angle coronagraphs, improving their ability to make these observations. But they still face another problem: Earth's atmosphere. The air in the atmosphere above the telescope is constantly moving, which causes the image to blur, and also absorbs much of the infrared radiation passing through it. Both VLT and Keck compensate for the unsteady air with adaptive optics, adjusting the mirror's shape to compensate for distortion, but they're still limited to observing in the narrow range of infrared wavelengths that can pass through our atmosphere. The only way to get around that issue is to get above the atmosphere.

Fortunately, NASA launched the James Webb Space Telescope on 25 December 2021 – a 6.5m-wide telescope designed to observe in the infrared part of the spectrum and which has a coronagraph. Once the telescope is in full scientific order in mid-2022, Biller will lead a team that will use Webb to directly image its first exoplanets – an exercise primarily intended to calibrate the telescope for Webb's future exoplanet observations. When it's up to speed, JWST should be capable of detecting young planets down to the size of Uranus or Neptune.

The real advantage of Webb, however, is that it isn't limited to seeing only wavelengths of infrared

Picturing planets

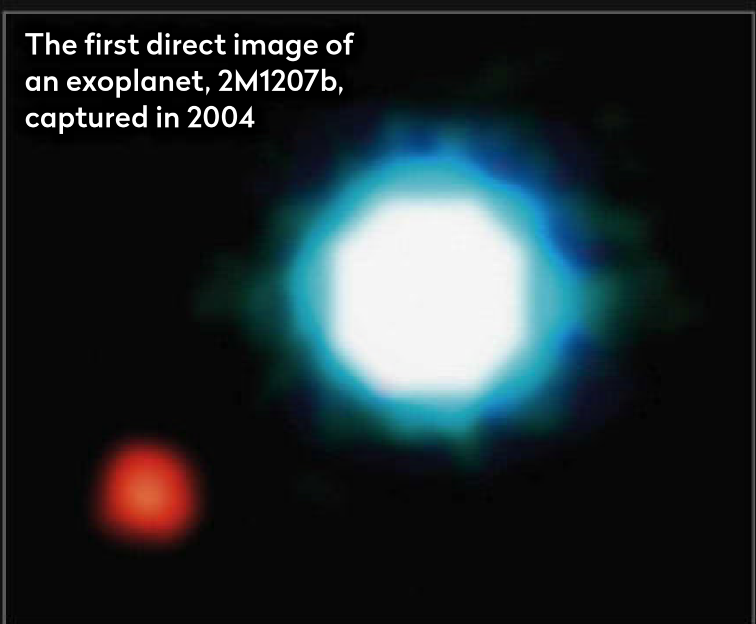
Even when taking direct images, it's not always clear cut if you've caught one

The first direct image of an exoplanet was captured in 2004 by the Very Large Telescope. The planet, named 2M1207b, is around five times the mass of Jupiter, orbiting 42 AU from a brown dwarf star in the TW Hydrae association of stars, around 200 lightyears from Earth and a youthful 8 million years old.

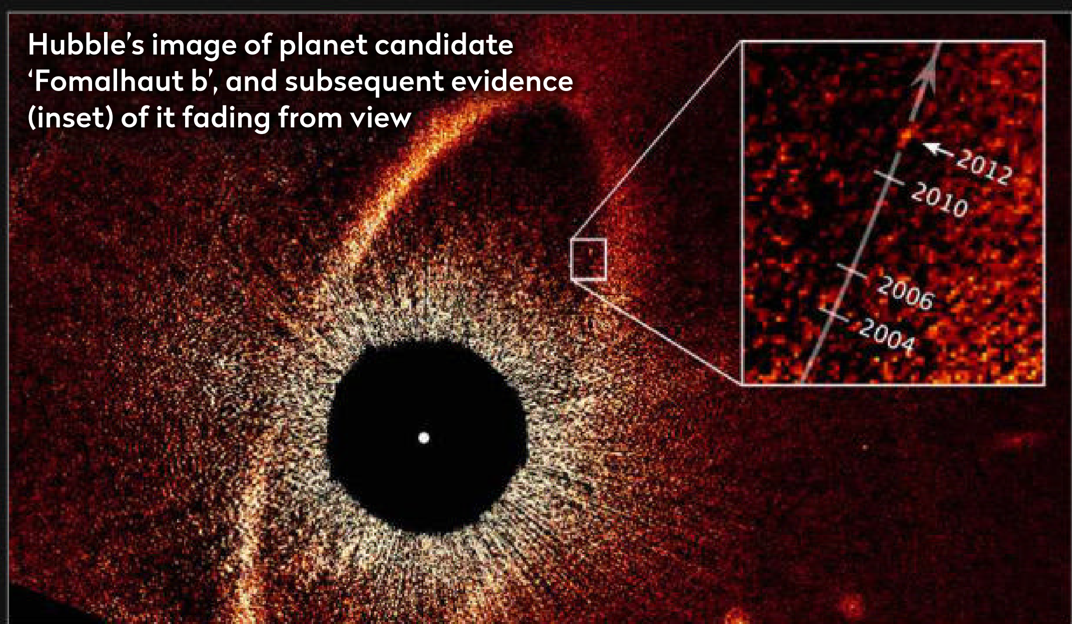
More exoplanets have been directly imaged since then, but the difficulty in seeing such distant worlds means many of these observations remain controversial.

"In terms of exoplanet detections we think are solid, there are around 20," says the University of Edinburgh's Professor Beth Biller. "It's something we fight about at conferences; the **Exoplanet.eu** database lists 100 or so directly imaged exoplanets, but some are pretty suspect."

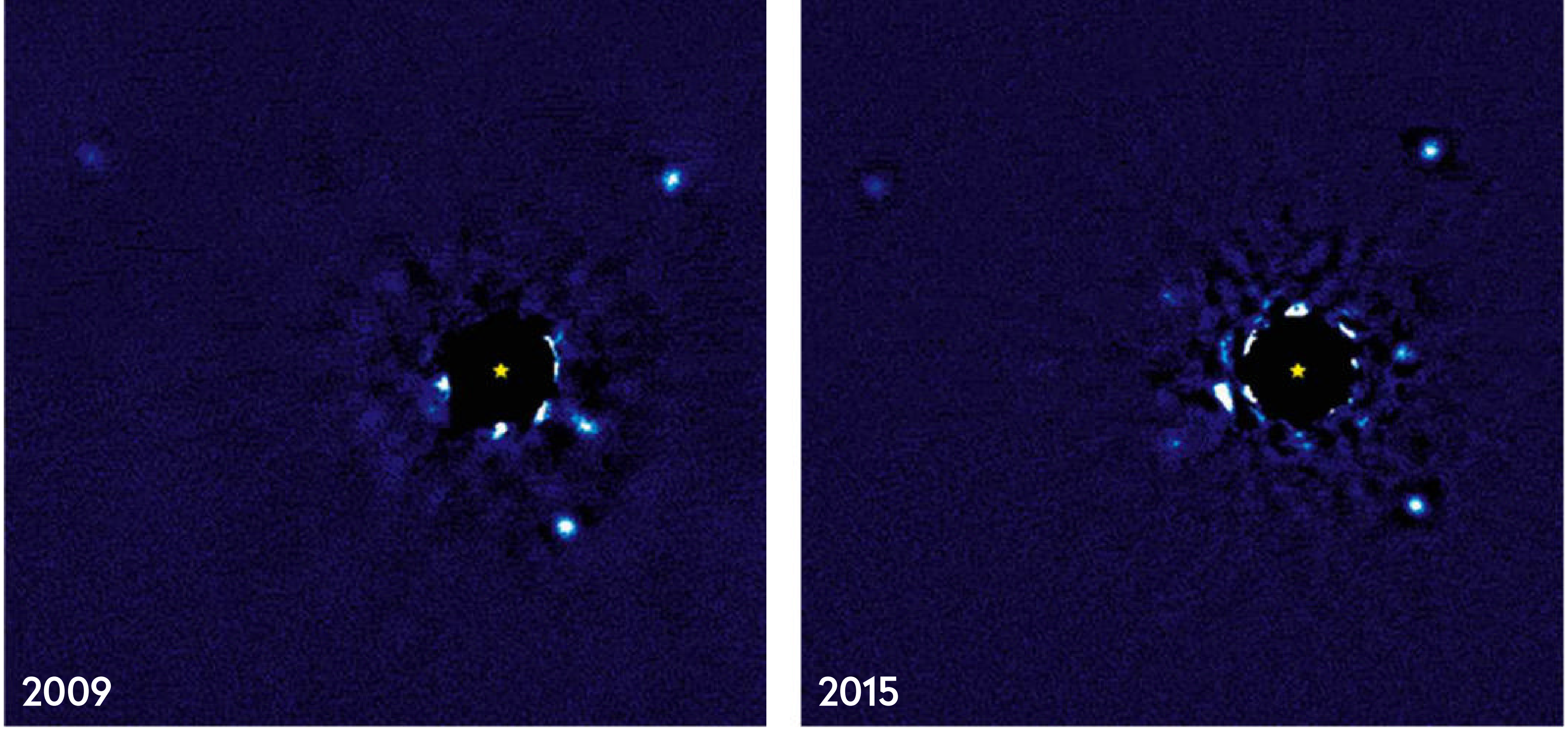
One of the biggest controversies surrounds the planet 'discovered' orbiting the star Fomalhaut in 2008. The star is clearly surrounded by a dust disc with a sharp inner edge, suggesting a planet clearing out the dust. It didn't take long for astronomers to find a bright object in the disc and announce they'd found a planet, only for it to fade over the next few years. After much debate, the object was officially removed from NASA's exoplanet archive in 2020. Though it's still widely believed there's a planet around Fomalhaut, it's probably hidden among the dust of the disc. It just goes to show that seeing isn't always believing when it comes to direct imaging.



The first direct image of an exoplanet, 2M1207b, captured in 2004



Hubble's image of planet candidate 'Fomalhaut b', and subsequent evidence (inset) of it fading from view



▲ **By using the Keck Observatory and its telescopes equipped with coronagraphs to obscure the light from the star HR 8799, astronomers Jason Wang and Dr Christian Marois were able to capture these images of four planets orbiting the star over six years**

▲ **The Extremely Large Telescope is currently under construction in northern Chile's Atacama Desert**

light that can pass through Earth's atmosphere; its position in deep space gives it access to infrared wavelengths denied to ground-based observatories.

"If you take pictures over different wavelengths, you can look at the distribution of spectral energy for your object," says Biller. "And spectroscopy is a powerful tool for understanding the atmospheres of these objects."

Clues to the emergence of life

As well as helping to give a better idea of what planets outside the Solar System are like, these types of observations will also help to solve other mysteries, such as how life evolved on Earth and whether it could have evolved elsewhere. ALMA has already shown that several planet-forming discs contain simple organic molecules – the building blocks of life. Discovering that these are present before a planet forms, and don't necessarily have to be created later, would have a huge impact on our theories of how life evolves.

"Another thing we're looking at is following how planets move over the course of several years, tracing out their orbits around a young star," Biller says.

As well as directly observing planets and the structure of planetary discs, astronomers use another well-established method to find and monitor exoplanets: radial velocity measurements. This method relies on closely monitoring a star in order to detect wobbles caused by an orbiting planet's gravity tugging on it. Sufficiently accurate measurements of the wobble reveal the masses of the orbiting planets.

"The goal is to look at how the distribution changes as a function of age," says Biller. "We don't expect these to be identical to what mature planets in our Solar System look like. We expect them to still be moving around in that state."

But even when all these methods of observation are combined, we still don't have a complete picture. Current telescopes – even the JWST – can only find gas giants that are far from their stars, beyond around 10 AU, which rules out the class of planets most eagerly sought after by exoplanet researchers: Earth-like planets.

"We hope to extend our methods to mature planets, which are colder, but that means moving to visual light," says Biller.

Doing so will require even more advanced telescopes, such as the Large Ultraviolet Optical Infrared Telescope (LUVOIR), a multiwavelength space telescope with a potential diameter of over 15m, currently being proposed by NASA as a successor to Webb. But while LUVOIR is still on the drawing board, there is a new generation of huge ground-based observatories with mirrors over 30m in diameter, known as Extremely Large Telescopes (ELTs), already under construction and expected to come online in the 2030s.

"The Extremely Large Telescopes will also be able to probe regions closer to the star, down to about 1 AU," explains Bae.

As our knowledge of mature exoplanets has grown, their more youthful counterparts have remained hidden beyond the limits of our observing capabilities. But over the coming years, as more advanced telescopes come online, these worlds will begin to emerge from the shadows and reveal the history of planetary systems like our own.

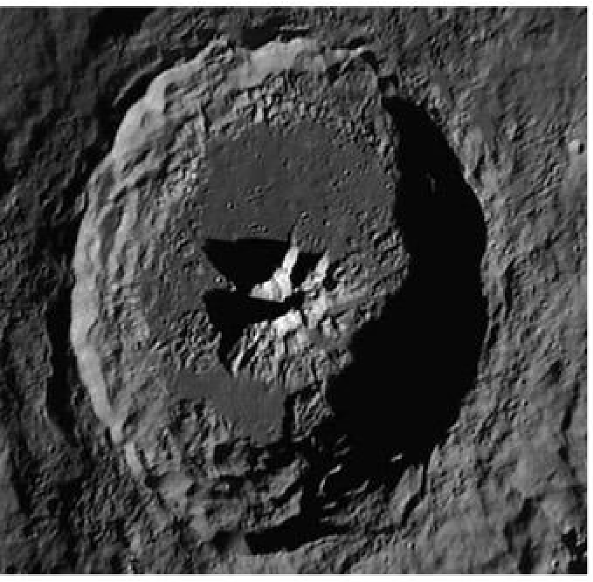
Dr Ezzy Pearson is *BBC Sky at Night Magazine*'s news editor. Her book *Robots in Space* is available through History Press

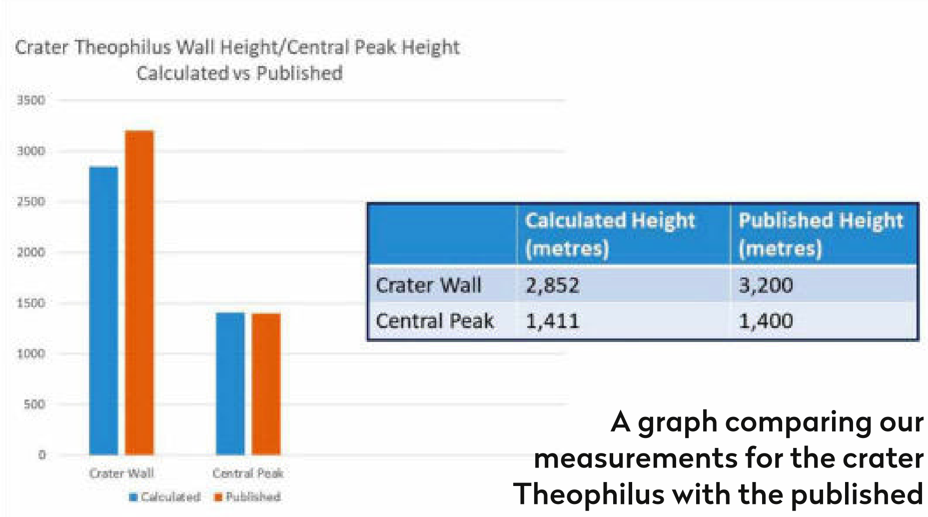
Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Use Moon shadows to measure crater peaks

How a simple formula gives you a deeper understanding of the physical form of lunar craters





	Calculated Height (metres)	Published Height (metres)
Crater Wall	2,852	3,200
Central Peak	1,411	1,400

A graph comparing our measurements for the crater Theophilus with the published data shows the results are similar

▲ Lunar craters like Theophilus shown here, with clear wall shadows and an interesting central feature, make good examples for measuring physical heights

The lunar surface is at its most striking when there are well-defined shadows. As well as being visually pleasing, the study of shadows cast by lunar mountains and craters can tell us a lot about these features. When we see a lunar crater from above it's easy to think that the crater wall is uniform around the entire perimeter. However, if we look at the shape of the shadows cast by a crater wall, we can get a clearer sense of the peaks and troughs along the rim; and if the crater has a central peak its shadows will reveal its nature too.

Here, we will show you a straightforward method to measure these shadows. By using some simple right-angled triangle trigonometry we can calculate the height of the lunar feature casting the shadow. Our equation is: O = tanθ x A; where O = 'opposite' (ie the height of the feature), tanθ = the tangent of the Sun angle, and A = 'adjacent' (ie the length of the shadow).

Timing is important

To get started all you need is a ruler, a calculator and a photo of a crater that has clear shadows. You need the time and date the photo was taken, so you can use the Lunar Terminator Visualization Tool (**bit.ly/3taEmyf**) to find out what the Sun angle was at that time, at any point on the lunar surface. We used a photo of crater Theophilus taken (by Alessandro Bianconi) at 03:48 UT on 18 September 2011.

It is important to mention that our process here has been simplified. This method relies on a published crater diameter so we can scale up our shadow measurement. Most craters are not perfectly circular, so the published figure is an average; we only took one diameter measurement. If you use this calculation for an isolated feature, you'll need to know the pixel/kilometre ratio for the equipment used to take photo.

Additionally, our process doesn't take the curvature of the lunar surface into account. Remember, the Moon is a sphere, so if you chose a crater that is quite central, the foreshortening effects are less apparent. It can also be difficult to know exactly where the shadow starts and ends if it's located in a complex region. We are only using a single measurement of a complex crater at one Sun angle and comparing that to a published figure, which will be an average value.

Our method brings a sense of scale to an otherwise abstract landscape. Even though it has been simplified to make the maths easier, it still yields results that are close to the published figure. This project will help you to gain a deeper awareness of the lunar features you choose to analyse.

Mary McIntyre is an outreach astronomer and teacher of astrophotography

What you'll need

▶ A high-resolution digital photo of a lunar crater that has clearly defined shadows; we used a photo of the crater Theophilus.

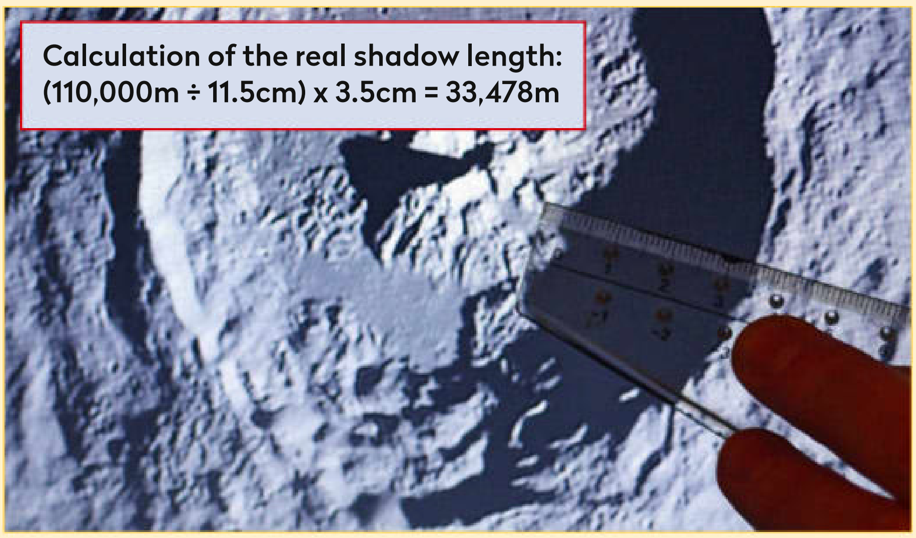
▶ A ruler; we used it to measure the shadow lengths on the computer screen, but you can use Photoshop's measuring tool or a printed photo.

▶ A scientific calculator with a tan button. If you use Excel for these calculations, convert the Sun angle from degrees to radians first.

▶ A copy of the Lunar Terminator Visualization Tool (VLT), which you can download from **bit.ly/3taEmyf**.

▶ The published crater diameter figure for the crater you're measuring from this online list of near-side craters: **bit.ly/3GQNFYb**

Step by step

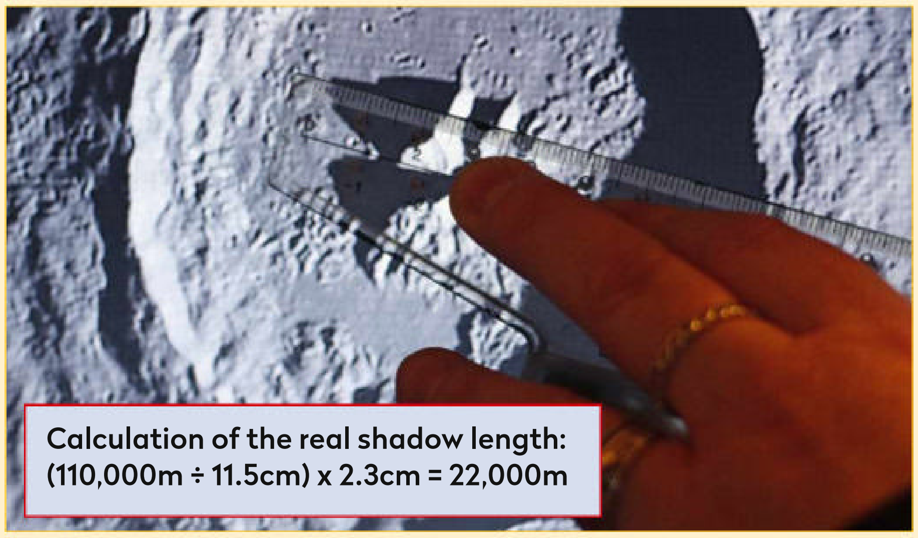


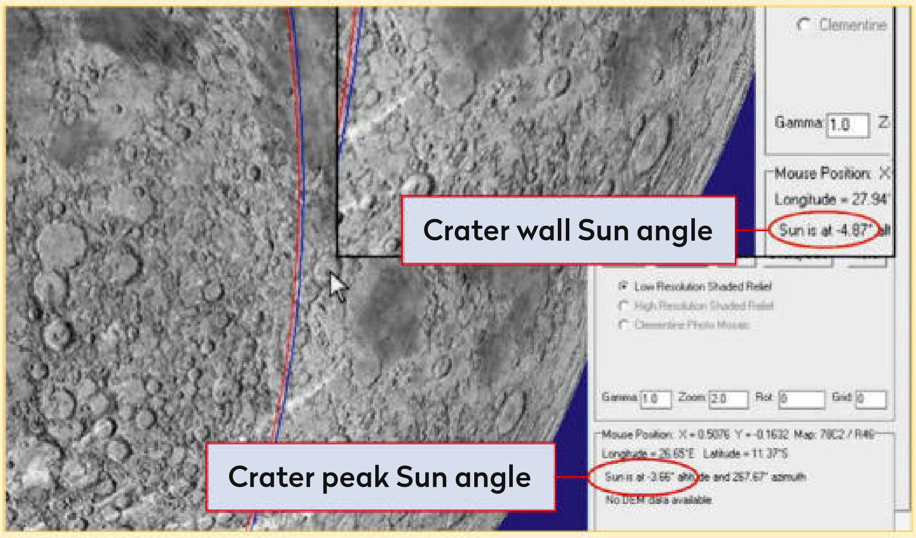
Step 1

Open your crater photo and view it full screen. Next, use a ruler to measure the diameter of the crater. We measured our example, Theophilus, at the widest point in the same direction that the shadows lie and got a figure of 11.5cm.

Step 2

Measure the crater wall shadow; we got a value of 3.5cm. Calculate the real length of the shadow by taking the published diameter (110,000m) and dividing by the diameter on screen (11.5cm), then multiply by the shadow length on screen (3.5cm) to get 33,478m.



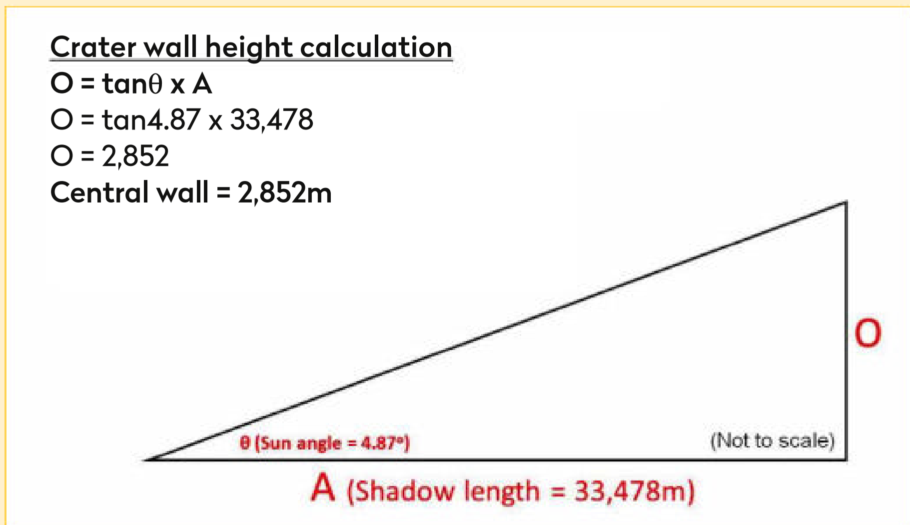


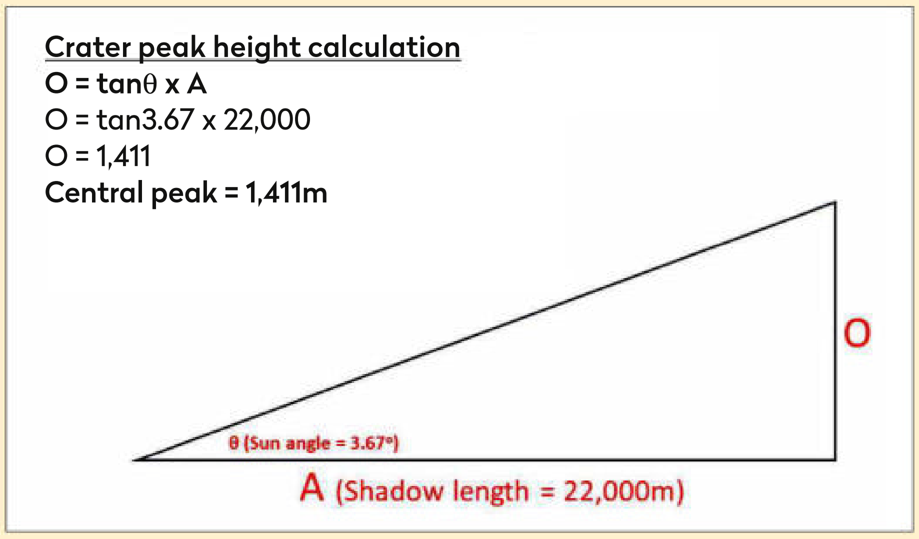
Step 3

Measure the crater's central peak shadow; we got a value of 2.3cm. Calculate the real length of the shadow by taking the published diameter (110,000m) and divide by the one on screen (11.5cm), then multiply by the shadow length on screen (2.3cm) to get 22,000m.

Step 4

Open the Lunar Terminator Visualization Tool (**bit.ly/3taEmyf**) and input the observation's date and time. Point the mouse at the point you began the crater wall shadow measurement and read the Sun angle; we got 4.87°. Repeat for the central peak; we got 3.67°.





Step 5

To calculate the height of the crater wall, use O = tanθ x A, where tanθ = tan4.87° and A = shadow length of 33,478m. When we applied this to the crater wall in our example, we calculated a height of 2,852m compared to the published value of 3,200m.

Step 6

To calculate the height of the crater's central peak, use O = tanθ x A, where tanθ = tan3.67° and A = shadow length of 22,000m. In our example, we calculated a height of 1,411m, compared to the published value of 1,400m.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Image a crescent and a cluster

Observe and shoot the Moon as it crosses paths with the Seven Sisters this spring

The early months of the year are great for observing, imaging or simply appreciating the beauty of the waxing crescent Moon. This is because the plane of Earth's orbit (the ecliptic) makes a steep angle with the western horizon after sunset. The Moon's orbit is inclined to the ecliptic by 5°, meaning the Moon never wanders too far from the ecliptic's position in the sky. As a consequence, at this time of the year, the earlier phases of the Moon are presented at their best.

At the same time, the constellation of Taurus, the Bull, is positioned above the western horizon in the early evening sky, which presents us with an opportunity to capture the waxing crescent Moon with that most beautiful of star clusters, the Pleiades or M45.

Also known as the Seven Sisters, the Pleiades sits 4.2° north of the ecliptic. This means that it lies within the Moon's corridor of motion across the sky and, at certain times, it's possible to see the Moon pass in front of the cluster stars. This is not the case currently, with the Moon appearing to pass below the cluster, but this can be a beautiful scene to capture too. In this article we will show you how to do this.

The months of February, March and April are optimal for a shot of the waxing crescent Moon and the Pleiades. Any earlier and the Moon's phase will be too great – its glare burning out the cluster's delicate stars; any later and the Pleiades will be doing battle with the evening twilight and their impact will be lost. There's a chance to capture both objects on the evenings of 7–9 March, with the smallest separation occurring on 8 March. There's another chance on 4 and 5 April, when the Moon's crescent will be thinner and better matched to the cluster.

▲ With careful framing you can capture the Moon and the Pleiades in one stunning image

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

You can capture the Moon and the Pleiades with different types of camera, but for the best results consider using a device with good manual control, such as a DSLR camera or MILC (mirrorless interchangeable-lens camera).

A good choice of field of view can make or break a photograph like this. As the sky darkens, both objects will get closer to the western horizon. In March there's a fair amount of time between the sky getting properly dark and the Moon and Pleiades setting, while in April there's a bit less time. If there's something interesting in the foreground, consider using it in the shot. For this you'll need a field of view that can contain both objects and sufficient foreground horizon to prevent the image appearing cramped.

The Pleiades is a deep-sky object that typically requires a multi-second exposure to capture well, while the Moon is a bright, extended Solar System object that will overexpose using longer exposures. This puzzle may seem impossible to solve, but with a bit of creativity you can produce some amazing results. Also, if clouds are present, you could use them to introduce some extra detail into the image.

Equipment: a DSLR camera or MILC (mirrorless interchangeable-lens camera)

✉ Send your images to: gallery@skyatnightmagazine.com

Step by step

STEP 1

Work out the field of view required to capture the Moon and Pleiades when the sky is clear. If you're planning to incorporate foreground scenery, a larger field is needed. A good maximum to consider is a long axis coverage of around 28°, using a 40mm lens on a non-full frame camera or 65mm for full frame.

STEP 2

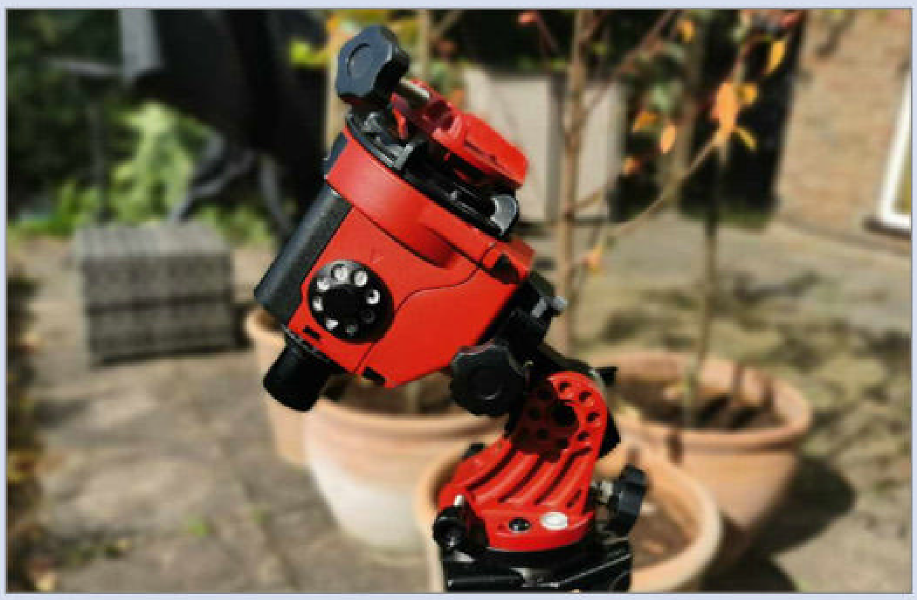
You'll need a dark sky to get the best results, which means photographing after 20:00 UT in March or 22:00 BST (21:00 UT) in April. Pick a location with no high foreground objects that might hide the Moon or Pleiades. You'll have more time to gauge what's happening in March (the two objects set earlier in April).

STEP 3

If you don't have a MILC or DSLR camera, you may be able to capture the scene with a smartphone, depending on its sensitivity to low light conditions. By all means use your phone camera's zoom function, but if it has optical and digital zoom, you're better off using the optical zoom to maintain quality.

STEP 4

Frame your shot and focus on the Moon. Set a low to mid ISO, say 1,600–3,200, then fully open the lens and increase the f/-number by a stop or two to prevent edge distortion. For a fixed tripod, use up to a maximum exposure (in seconds) of 500 divided by the focal length of your lens (in millimetres).



STEP 5

With a tracking mount you can increase the maximum exposure, but be careful not to over expose the Moon. A tracking mount also lets you to stop the lens down further, increasing exposure time to compensate. Using say, f/11, the aperture blades of the lens should create diffraction spikes from the bright Moon.

STEP 6

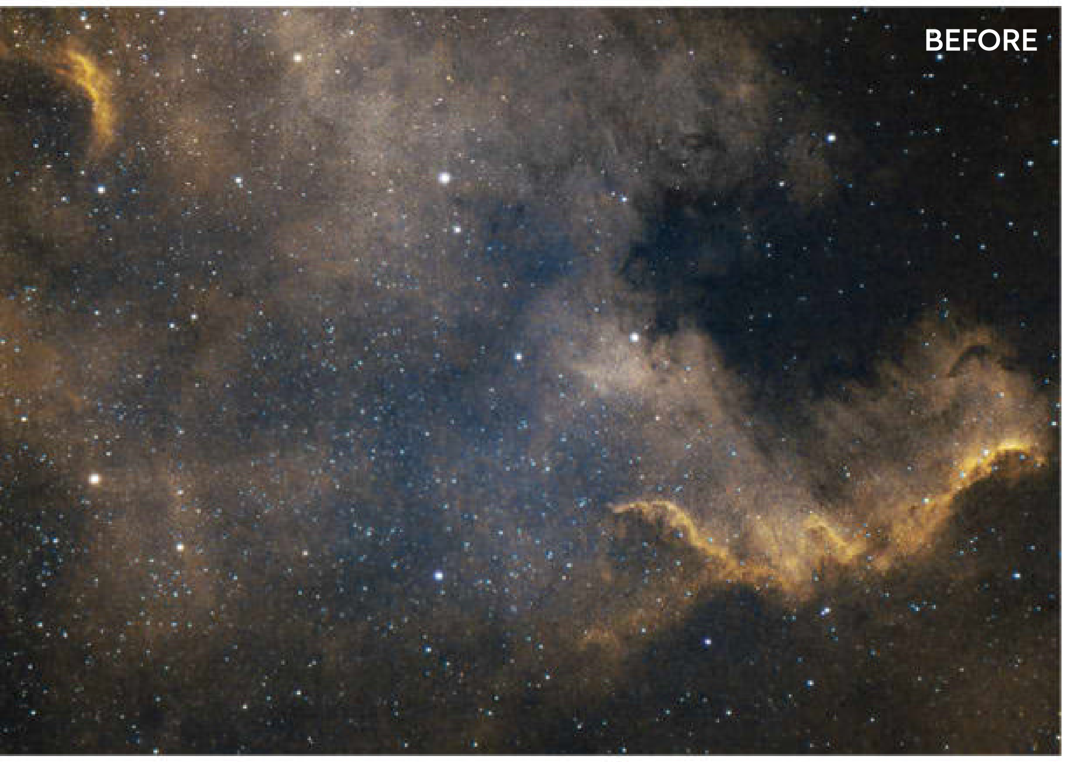
If patchy clouds interfere, use these to good effect. If the cloud is broken and thin, it may even be possible to time your shot so the Pleiades is seen under clear sky while the Moon is reduced in brightness by cloud. This can allow you to really bring out detail in the cluster without the Moon dominating the shot.

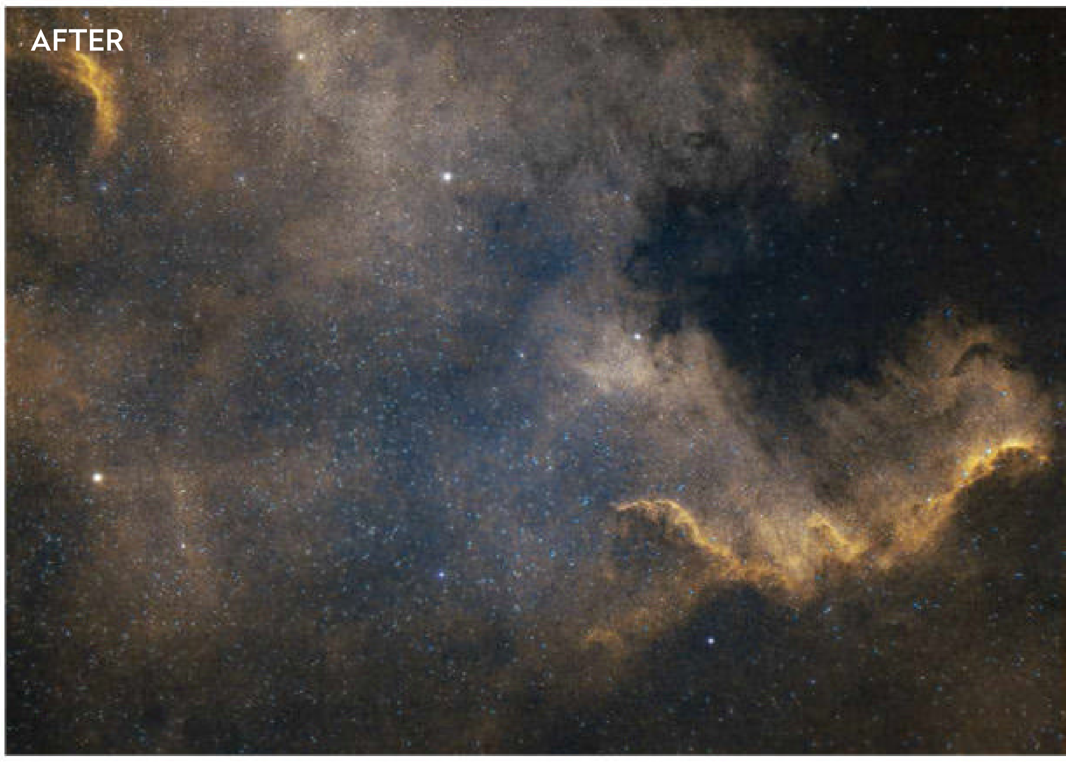
Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Use StarShrink to improve nebula images

This Photoshop plug-in can bring out the natural deep-sky details by suppressing noise





▲ Left: the image of the North America Nebula before the StarShrink process is awash with noise (unwanted artefacts) and stars that are not clearly defined

Right: after StarShrink has been applied the image is much cleaner and the stars have a more natural appearance, allowing the fine detail of the nebula to be revealed

Removing image noise, or unwanted artefacts, is one of the main aims of deep-sky astrophotography processing. The more we can reduce noise, the more freedom it allows us to process our images of nebulae and galaxies. This is particularly true for nebulae, where delicate gaseous details are easily overwhelmed or hidden. There are various noise reduction tools to help overcome the issue, but care needs to be taken applying them; use them too heavily and the target will look soft or blurry. In this article we will show you how to apply just the right amount of adjustment to the stars in a deep-sky image of the North America Nebula by using a plug-in.

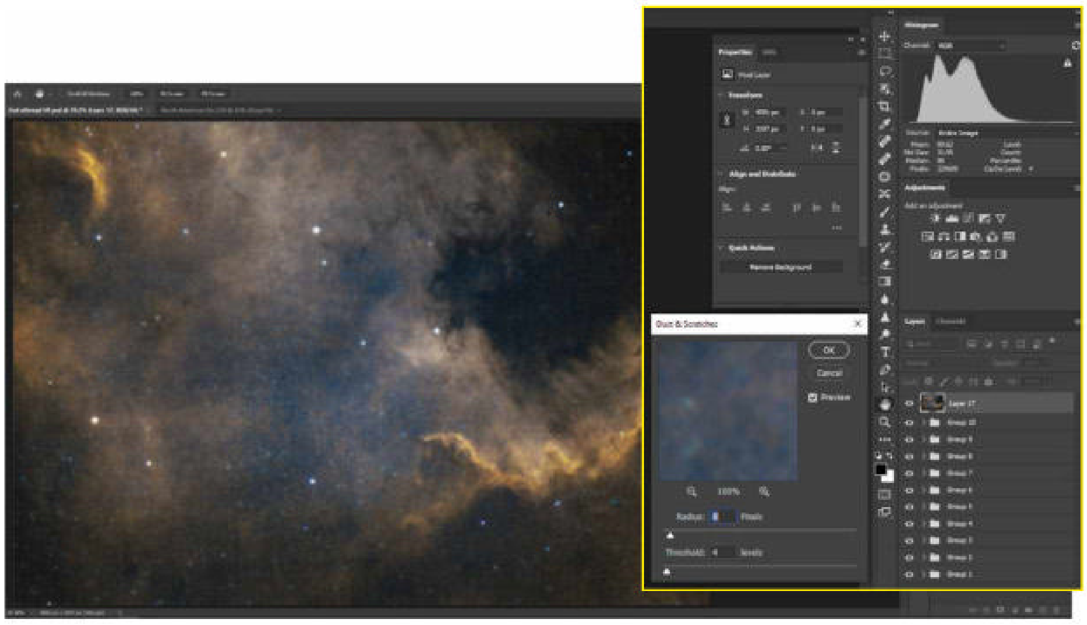
Stars are often one of the main causes of unwanted artefacts in astrophotos, and this complicates noise reduction processes because there are often hundreds, if not thousands of them in an image. One way to manage this is to remove stars from the image so that they can be processed separately. While software to remove stars exists (including StarNet++ in PixInsight) these work best for CCD cameras and can struggle with DSLR camera data. Also, if you are using Adobe Photoshop or GIMP image-editing software, it is often the case that both the nebula and stars must be processed at the same time. This is where a plug-in (software add-on) that specifically targets the appearance of the stars is very useful.

ALL PICTURES: CHARLOTTE DANIELS

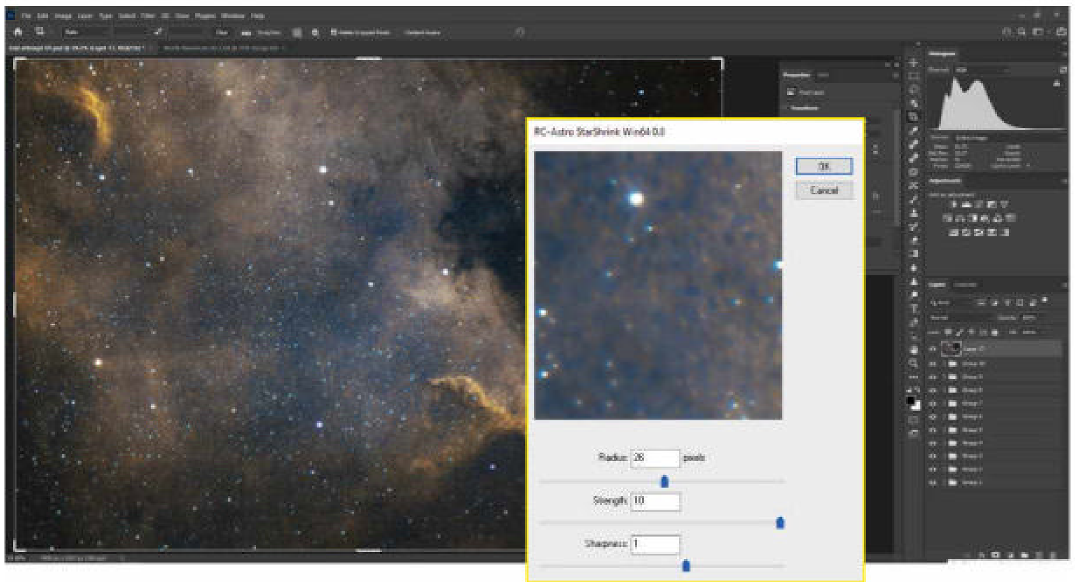
Getting ready

Here, we are going to run through how to use Russell Croman's 'StarShrink' plug-in to enhance an image of the North America Nebula in Photoshop. StarShrink is purchased and downloaded from his website at **www.rc-astro.com/resources.** It has a 30-day free trial and works with both Windows and MacOS operating systems. Once the file is downloaded, you need to locate it – for Windows computers it is found in 'C: drive › Downloads'. This file needs to be transferred to your Photoshop Plug-ins directory, the location of which is dependent on the version of Photoshop you are using. For Photoshop 2022 on a Windows computer, click and drag the file to: C:\Program Files\Common Files\Adobe\Plug-Ins\CC.

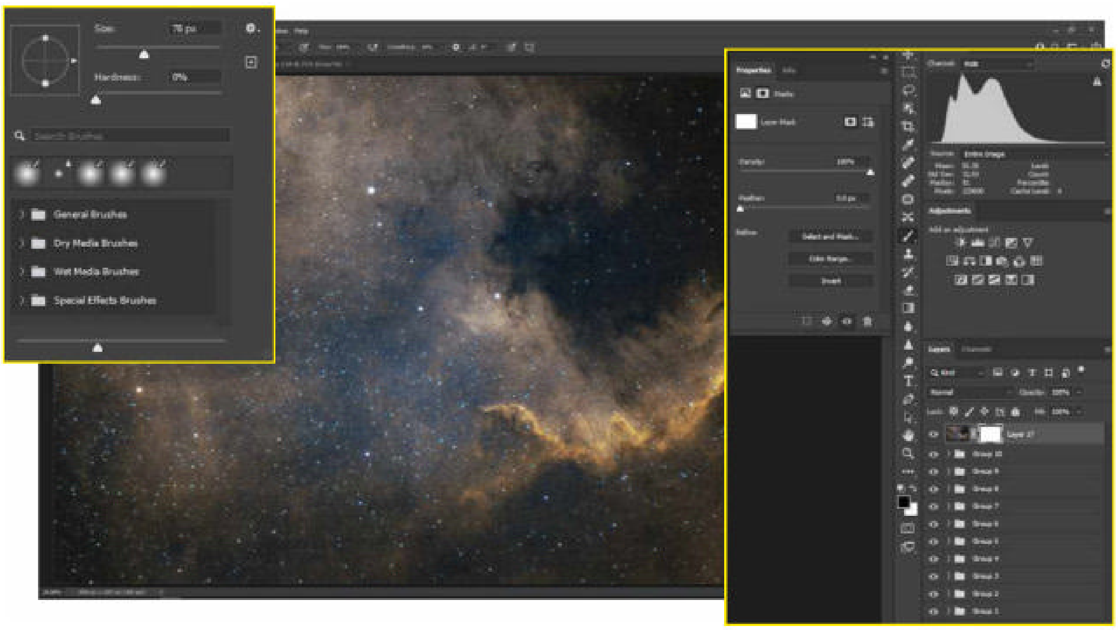
We recommend applying StarShrink at the end of your processing workflow, once adjustments to the main objects in a deep-sky image have been made.



▲ **Screenshot 1: be careful using 'Dust & Scratches' in Adobe Photoshop as this can soften the appearance of a target**



▲ **Screenshot 2: use StarShrink's preview window to focus on a particular region of your image while making slider adjustments**



▲ **Screenshot 3: by using a layer mask it is possible to select stars to leave unamended by the shrink**

The reason is because the appearance of the stars will change throughout most of the image amendments you make in Photoshop, often increasing their size. This is the case for our initial processing of the North America Nebula. In our example (see the 'Before' image, opposite, left) we have already made all adjustments required to maximise the appearance of the nebula itself, including 'Brightness/Contrast', 'Levels', 'Colour Balance' and 'Hue/Saturation'; all of which are accessed 'by clicking Image › Adjustments'. A median filter has also been applied, by selecting 'Filter › Noise › Median', to reduce some of the overall image noise, but the stars are still looking bloated in our image.

3 QUICK TIPS

1. Click and drag the image screen within StarShrink to see the effect of your adjustment.

2. If there are varying sizes of stars, apply StarShrink more than once and change the radius each time.

3. If using a mask, you can alter the brush size by using your bracket keys.

We can manage these stars to an extent, by applying 'Dust & Scratches', which is achieved by clicking 'Filter › Noise › Dust & Scratches', but it is easy to overdo this function and soften the appearance of the target (see Screenshot 1). So, in order to prevent this, we will use StarShrink to target and 'shrink' the stars.

Once the StarShrink plug-in is open, by clicking 'Filter › StarShrink', the preview window will focus on a region of your image (Screenshot 2). To move to another region, just click and drag within the window.

Starry adjustments

At the bottom of the preview window are three adjustment sliders. By moving the top one, 'Radius', you can adjust which stars will have a shrink applied; a smaller radius will target smaller stars. The middle slider, 'Strength', allows us to determine how strong the shrink we apply is, and the bottom slider option, 'Sharpness', helps to maintain a natural star profile. If the 'Sharpness' value is too high, stars will appear as tight white pinpricks with hard edges, but a lower value will retain colour around the stars' edges, allowing them to subtly complement the image.

Be careful not to shrink every star to the same size, as this can make your image look over-processed. While stars are responsible for noise, we don't want them to look artificial as they are still an important part of the overall image. We can use a layer mask to select any stars we'd like to leave unamended. Once we have performed a shrink, we can do this by clicking the mask icon with the star shrink layer we've highlighted (see Screenshot 3). Next, a white mask will appear next to the layer. After we have altered our brush size (see top left window in Screenshot 3) we paint over selected stars to undo the change and then choose which ones we want to stand out in our image. Be sure not to overdo the shrink, as this will create unwanted warping around the larger stars.

In our final image, you can see that the North America Nebula's starry regions are now far less noisy. The attractive, natural looking stars add to the depth and beauty of the deep-sky picture.

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

Your best photos submitted to the magazine this month

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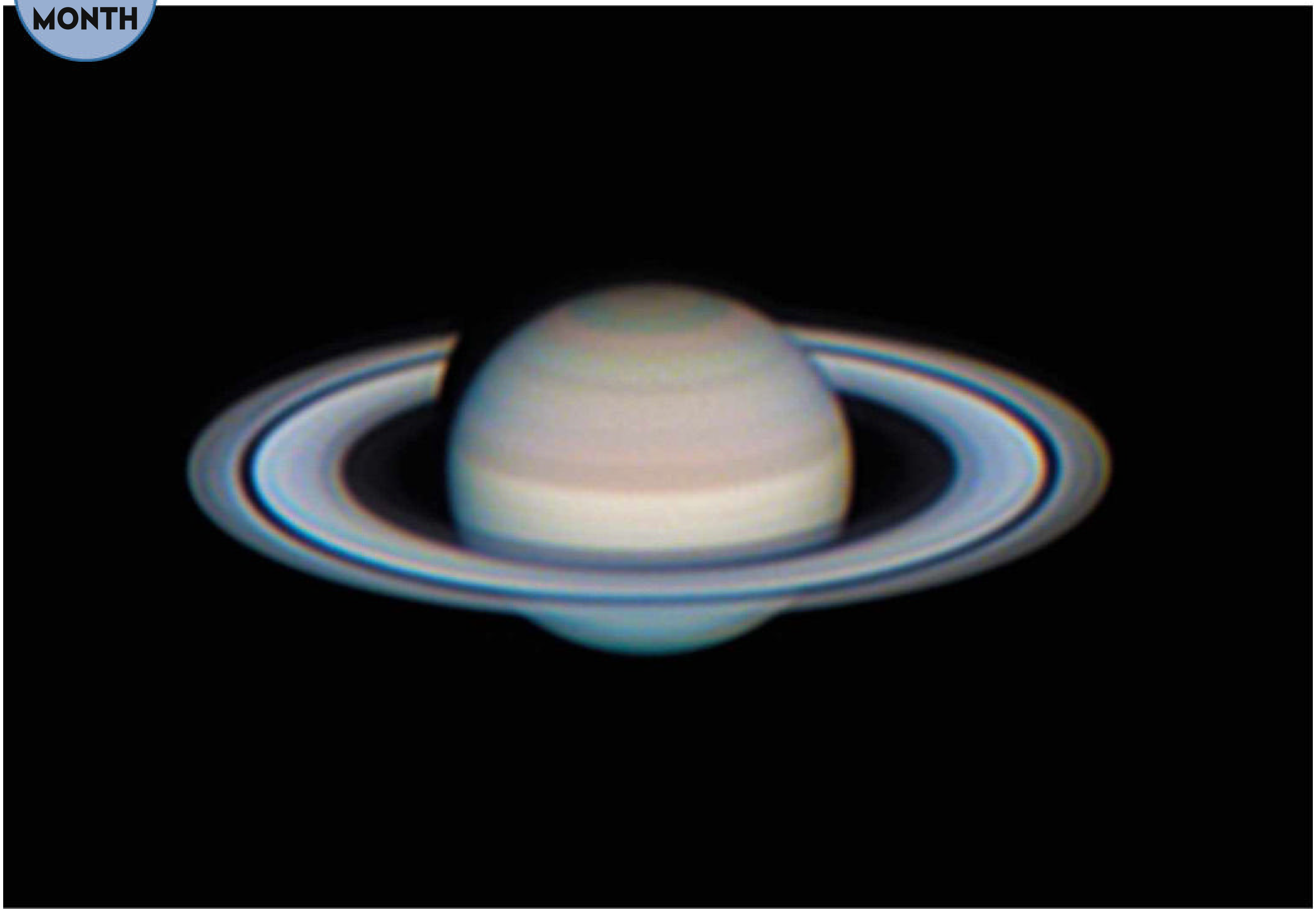
A gallery containing these and more of your images

PHOTO OF THE MONTH



△ Saturn

Prabhakaran (Prabhu), Fujairah, United Arab Emirates, 21 November 2021

Prabhu says: "At the time of this capture, Saturn was only 40° above the horizon. Generally, when the planets are low in the sky the atmospheric seeing makes it difficult, but if the seeing is excellent then by using an ADC (atmospheric dispersion corrector) one can capture a lot of the subtle details. This image was taken next to the United Arab Emirates' eastern coast in Fujairah, which has very good atmospheric seeing because of the stable temperature above the ocean. I was able to capture the planet's beauty by taking short videos; many of Saturn's rings and bands in its atmosphere are visible."

Equipment: ZWO ASI462MC camera, Celestron CPC Deluxe 1100 EdgeHD Schmidt-Cassegrain **Exposure:** 7.5', 50 per cent of best frames stacked **Software:** RegiStax, WinJupos, AutoStakkert!

Prabhu's top tips: "For planetary imaging, use a telescope that is eight inches (200mm) and above in size. Begin by checking online for seeing conditions and the global jet stream winds, then acclimatise your scope to avoid the tube currents interfering with the light path inside the scope and blurring the planet's details. Use an ADC (atmospheric dispersion corrector), especially if the target planet is low in altitude. A focal extender will magnify the planet; I used Explore Scientific's 3x focal extender. For best results, use a planetary camera with a high frame rate to capture as many short videos as possible, before using software for stacking and derotating your frames."

△ JWST going up

Samit Saha and Soumyadeep Mukherjee, Sukna, West Bengal, India, 25 December 2021

Soumyadeep says: "This shows Ariane 5 carrying the James Webb Space Telescope (JWST) past the Sculptor Galaxy, NGC 253."

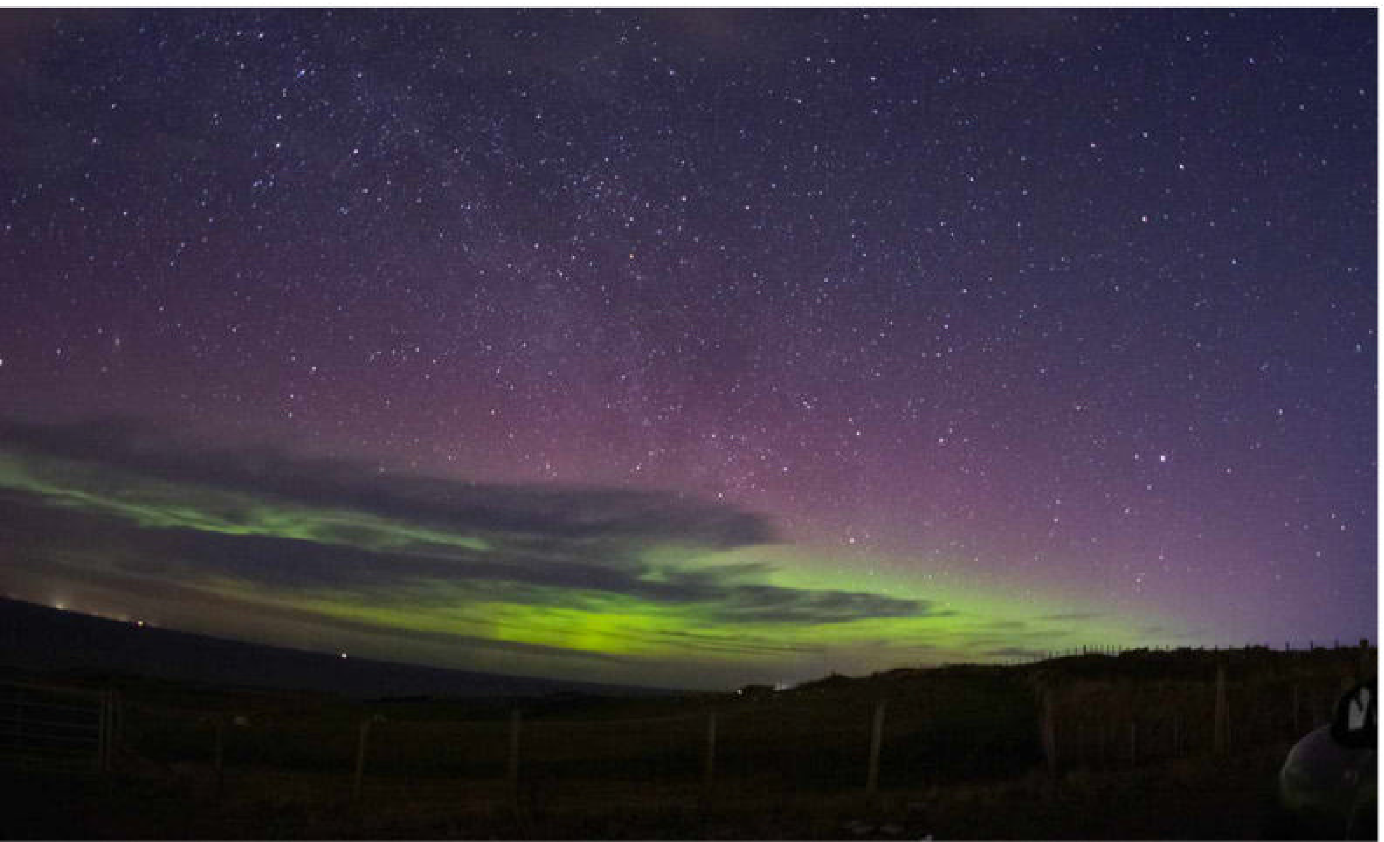
Equipment: Nikon D5600 DSLR camera, Samyang 135mm lens, iOptron SmartEQ Pro mount **Exposure:** ISO 500 f/2, 40x 2" **Software:** Sequator, PixInsight, Adobe Camera Raw, Adobe Photoshop

The Rosette Nebula ▷

Hannah Rochford, Bruton, Somerset, 10 December 2021, 3, 4 January 2022

Hannah says: "This is my first ever deep-sky photo in mono. I've only used a DSLR camera and lens before, so this is totally new to me!"

Equipment: ZWO ASI2600MM camera, Sky-Watcher Evostar 80ED refractor, Sky-Watcher EQ6-R mount **Exposure:** Ha 37x 300", OIII 36x 300", SII 34x 300" **Software:** DeepSkyStacker, Photoshop



◁ Aurora in Scotland

Emily Stephen, Fraserburgh, Aberdeenshire, 12 March 2021

Emily says: "I was using my new lens for the first time and was lucky enough to capture the Northern Lights a few miles from where I live."

Equipment: Nikon D3400 DSLR camera, Velbon EF-41 tripod **Exposure:** ISO 1600, 15" **Software:** Nikon NX Studio

△ The Andromeda Galaxy

Drew Evans, Flagstaff, Arizona, USA, November 2021

Drew says: "This image of M31 was captured with 25 hours of mono data in Bortle Class 4 skies."

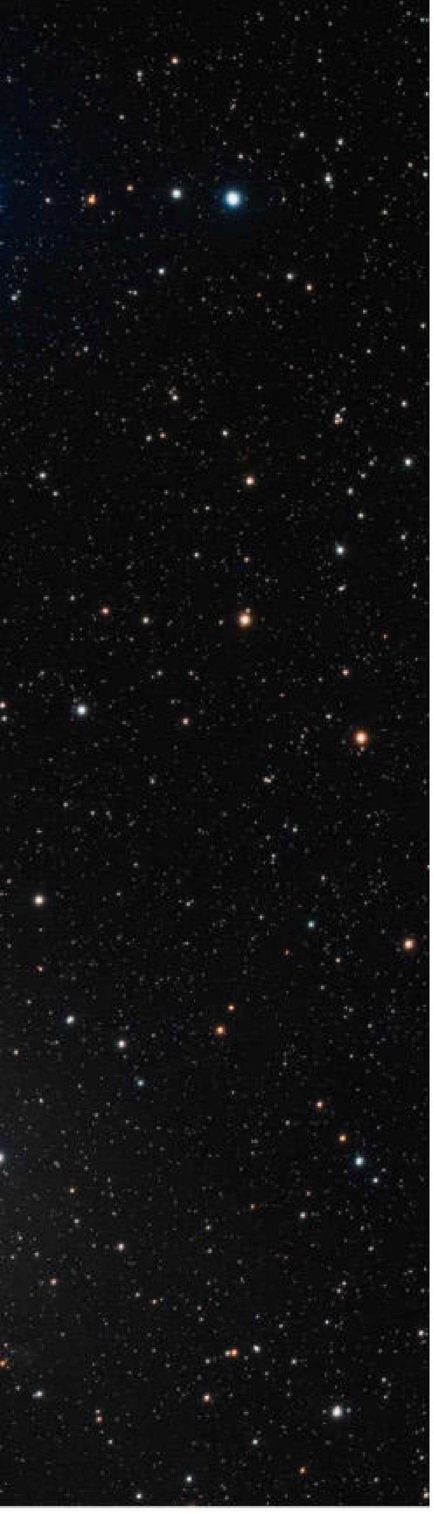
Equipment: ZWO ASI2600MM Pro camera, William Optics GT81 refractor, Celestron CGX-L mount **Exposure:** R 66x 300", G 53x 300", B 60x 300", L 88x 180", Hα 67x 300" **Software:** Astro Pixel Processor, PixInsight, Lightroom

△ Comet C/2021 A1 Leonard

Chris Morriss, Taupo, New Zealand, 26 December 2021

Chris says: "I was surprised how much detail I could capture in the comet's tail given the low altitude (about 14°) and a nearby streetlight shining into my telescope."

Equipment: ZWO ASI2600MC Pro camera, Celestron C11 Schmidt-Cassegrain, 10Micron GM1000 HPS mount **Exposure:** 15x 10" **Software:** Astro Pixel Processor, PixInsight, Adobe Photoshop



△ The Moon

Andrei Pleskatsevich, Minsk, Belarus, 2 September 2020

Andrei says: "I took this in a field one night as I tested my telescope after collimation."

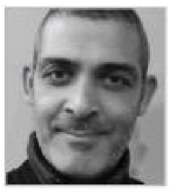
Equipment: Fujifilm X-T30 mirrorless camera, Celestron NexStar Evolution 9.25-inch Schmidt-Cassegrain

Exposure: 3' video, best 2,000 frames stacked

Software: PIPP, AutoStakkert!, Astra Image

◁ The Cone and Fox Fur Nebulae

Toni Fabiani Méndez, Àger, Lerida, Spain, Nov–Dec 2021



Toni says: "Honestly my best photo to date; I was very happy with the result."

Equipment: ZWO ASI183MM Pro camera, Sky-Watcher Esprit 100ED refractor, Sky-Watcher EQ6-R Pro mount

Exposure: Ha 44x 600", OIII 14x 600", SII 24x 600"

Software: PixInsight, Adobe Photoshop

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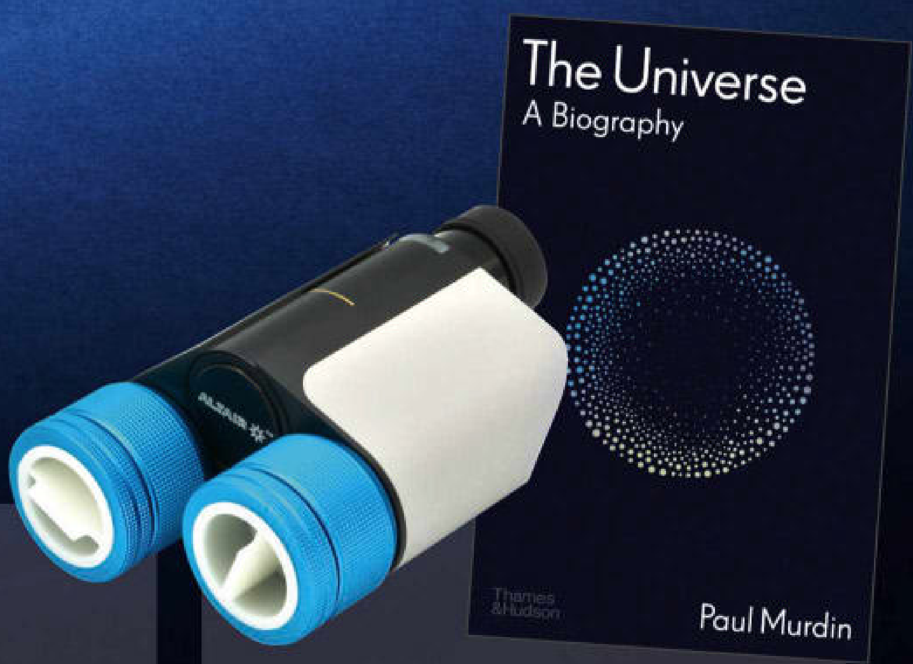
86

How well does the StellaMira 90mm ED telescope cover the bases when it comes to visual observing and astro imaging? We put it to the test on a range of targets



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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

PLUS: Books about the life story of the Universe and Mars missions, as well as a roundup of recommended gear

Our experts review the latest kit

FIRST LIGHT

StellaMira 90mm ED triplet apochromatic refractor

A sturdy, stylish scope that works wonders for visual observing and astro imaging

WORDS: TIM JARDINE

VITAL STATS

- **Price** £1,449
- **Optics** f/6 apochromatic triplet
- **Aperture** 90mm
- **Focal length** 540mm
- **Focuser** 2.5-inch rack and pinion
- **Extras** Tube rings and a carry case
- **OTA weight** 3.3kg
- **Supplier** First Light Optics
- **Email:** questions@firstlightoptics.com
- **www.**firstlightoptics.com

The StellaMira 90mm ED telescope on test this month is a triplet lens apochromatic refractor introduced by First Light Optics. We were especially interested to receive our review model, as the company has always been upfront on its website blog about any issues with triplet telescopes, with the promise of only releasing new ones when production methods allow consistently good results. It was fair to say, given that stance, that we had high expectations for the StellaMira 90mm ED.

The packaging of the StellaMira 90mm ED is compact; it is supplied in a neat, lockable, black carry case. The telescope has a sturdy construction, with a glossy carbon-fibre tube and dew shield. It certainly looks and feels like a quality piece of equipment, with anodised red aluminium highlights, black tube rings and a carry handle. Although the carbon-fibre tube keeps the weight down to a mere 3.3kg, the StellaMira 90mm ED doesn't feel flimsy or compromised in any way whatsoever.

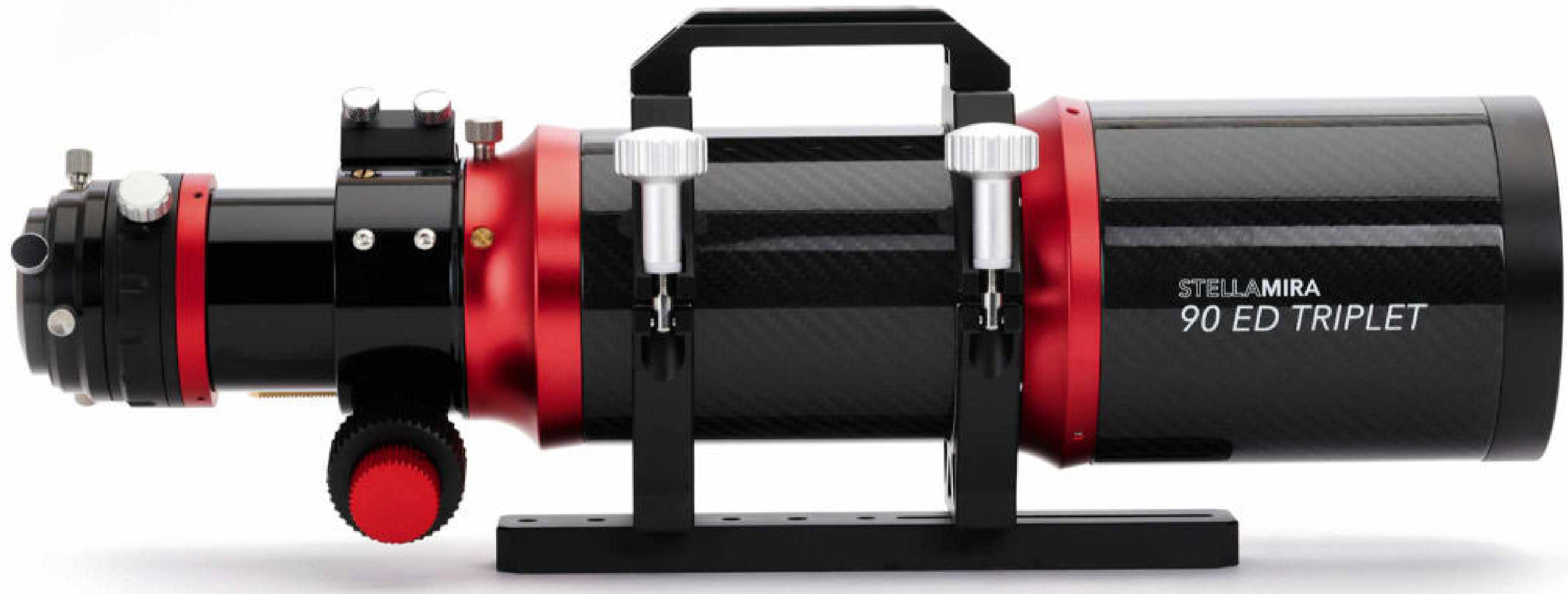
The 90mm lens of the StellaMira telescope has a focal length of 540mm, making it a speedy f/6, and perfectly suited to astrophotography, especially with its focuser design. There's no reason why it can't also be used as a high-quality, wide-field visual instrument. Indeed, it's fitted with a removable holder (for 2-inch and 1.25-inch eyepieces or a diagonal) with brass compression rings.

Sharp focus

To test the StellaMira 90mm ED's astrophotography abilities we paired it with a StellaMira 0.8x reducer/flattener. This threads firmly onto the focuser, after unscrewing the eyepiece clamp, and the M48 thread on the rear allows a camera to be attached with a spacing of 55mm, which is ideal for DSLR cameras.

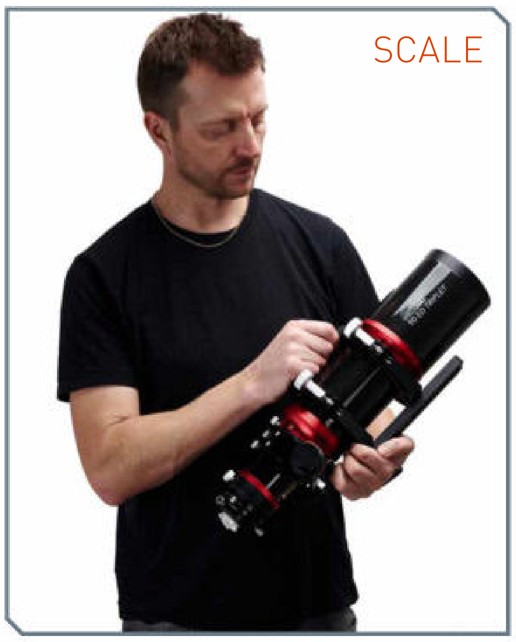
With the reducer in place the telescope offers a coma-free image field up to APS-C sensor size. Test pictures were taken using a CCD camera and the back spacing was a few millimetres out, resulting in slightly skewed stars in the corners. But a selection of reference images (taken with a full-frame DSLR and the correct spacing) showed the true flat field on offer, which covers 36mm x 24mm. All the stars, except those on the outer edges of the full-frame image, appeared round and sharp.

When it comes to imaging, the focuser arrangement is particularly impressive. The whole ▸



ALL PICTURES: @THESHED/PHOTOSTUDIO

SCALE



Focuser

The rotatable focuser is a 2.5-inch rack and pinion design with millimetre graduations on the drawtube. The action is smooth and responsive, and, with 1:10 gearing, is perfect for accurate fine focusing. The integrated camera angle adjuster further allows for separate, easy rotation of the camera through a 360° range.

Tube rings and handle

The CNC-machined tube rings and fittings provide a solid, secure setting for the StellaMira 90mm ED. They sit atop a Vixen-style, dovetail bar and incorporate a combined carry handle and accessory rail. An additional Synta-style finderscope shoe is mounted to the rotatable body of the focuser.

Carbon-fibre tube

The lightweight, carbon-fibre tube assembly offers a stylish outward appearance combined with intrinsic strength and rigidity. Carbon-fibre offers greater thermal stability than aluminium during astrophotography sessions, so potentially fewer images are lost to soft focus when outside temperatures change rapidly and expansion or contraction alters the focal point.

A superior objective triplet lens

The 90mm objective lens in the StellaMira 90 telescope is made from Extra Low Dispersion (ED) glass, equivalent to FPL-53, and the optics are fully multi-coated for high light transmission and better contrast at the eyepiece/camera. The triplet lens design allows the telescope to bring the varying colours of light to the same point of focus. At the eyepiece, this results in sharp planetary or star images, but the good colour correction is more noticeable on bright targets such as the Moon or major planets, as inferior optics produce haloes or rings on the bright edges. When used for astrophotography, the StellaMira 90mm's good colour correction is evidenced by sharp, tight star images. You can test this by photographing the bright, blue stars in the Pleiades and then comparing the pixel sizes of the resulting images, after splitting them into Red, Green and Blue channels. The different colour star layers we produced overlapped each other almost perfectly, pixel for pixel, demonstrating the true apochromatic fidelity of the StellaMira 90mm ED telescope.

Optical report and quality control

Each StellaMira 90mm ED telescope comes with its own optical report from the factory and a guaranteed minimum Strehl ratio of 0.95 (an indicator of its optical quality). In addition, prior to shipping to customers, each telescope is checked on the supplier's in-house optical bench, and the focuser and fittings are quality checked too.

Carry case

The StellaMira 90mm ED is lightweight, compact and highly portable. It can be transported safely in the dedicated aluminium case, which has foam cut-outs that hold the telescope snugly. The whole package (case included) weighs just over 4kg, making it great for use as a high-quality travel telescope.

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KIT TO ADD

1. StellaMira 2-inch 0.8x reducer/ field-flattener

2. Astro Essentials 32mm f/4 mini guidescope

3. StellaMira 2-inch 90° Di-electric diagonal

▸ focuser body rotates, allowing the control knobs to be conveniently positioned, while a separate camera rotator allows adjustment of the camera angle. Fast optical systems have a very shallow depth of focus, requiring precision movements; and in this regard we found the rack and pinion design to be smooth and impressively accurate, especially when making micro-adjustments for perfect focus

Testing the limits

Winter skies offer a host of targets, but the Pleiades, M45, and the Orion Nebula, M42, offer pretty much everything an astrophotographer might encounter, including bright dominating stars, faint reflection nebulosity, rich and thin emission nebulae, and tight star groupings that test the telescope's limits.

The hot blue stars within M45 can produce unwanted artefacts (haloes around stars, irregular diffraction patterns or internal reflections) in poorly configured optics, while the tight star grouping within M42's Trapezium Cluster can be mangled into an indistinct blob, but our images were clear of these issues. Instead, the StellaMira 90mm ED produced excellent results, which were consistent with the impressive 0.972 Strehl ratio rating given for this particular telescope (a measure of its optical quality). There were even tantalising hints of the Trapezium stars 'E' (Theta^1 (θ^1) Orionis E) and 'F' (Theta^1 (θ^1) Orionis F) in M42 during the camera focusing procedure.

Briefly swapping the camera for an eyepiece was similarly rewarding and delivered excellent views of Jupiter, even using a Barlow lens to boost a 4.5mm eyepiece up to a boundary-stretching 240x magnification. This produced a sharp, detail-rich image, free of any unwanted colour aberrations, again testifying to the high-quality optics.

Overall, the StellaMira 90mm ED Triplet more than met our expectations. It's a competitively priced, stylish telescope that offers excellent views and high-quality astro imaging results in a convenient, well thought out package.

VERDICT

Build & design	★★★★★
Ease of use	★★★★★
Features	★★★★½
Imaging quality	★★★★½
Optics	★★★★★
OVERALL	★★★★★

▲ A detail-rich image of M42, captured with the StellaMira 90mm ED and an Atik 460ex OSC camera, using 20x 60" exposures and 20 minutes of integration

▲ The Pleiades, M45, captured with the same setup – using 600" exposures and a total integration of 3 hours and 40 minutes – reveals vibrant, rich textures

Star-Hop Maker observing program

An easy to navigate software that automates your star-hopping needs

WORDS: STEVE RICHARDS

▲ The main screen of Star-Hop Maker (inset) has easy-to-navigate features, including the 'Sky-Chart' area

VITAL STATS

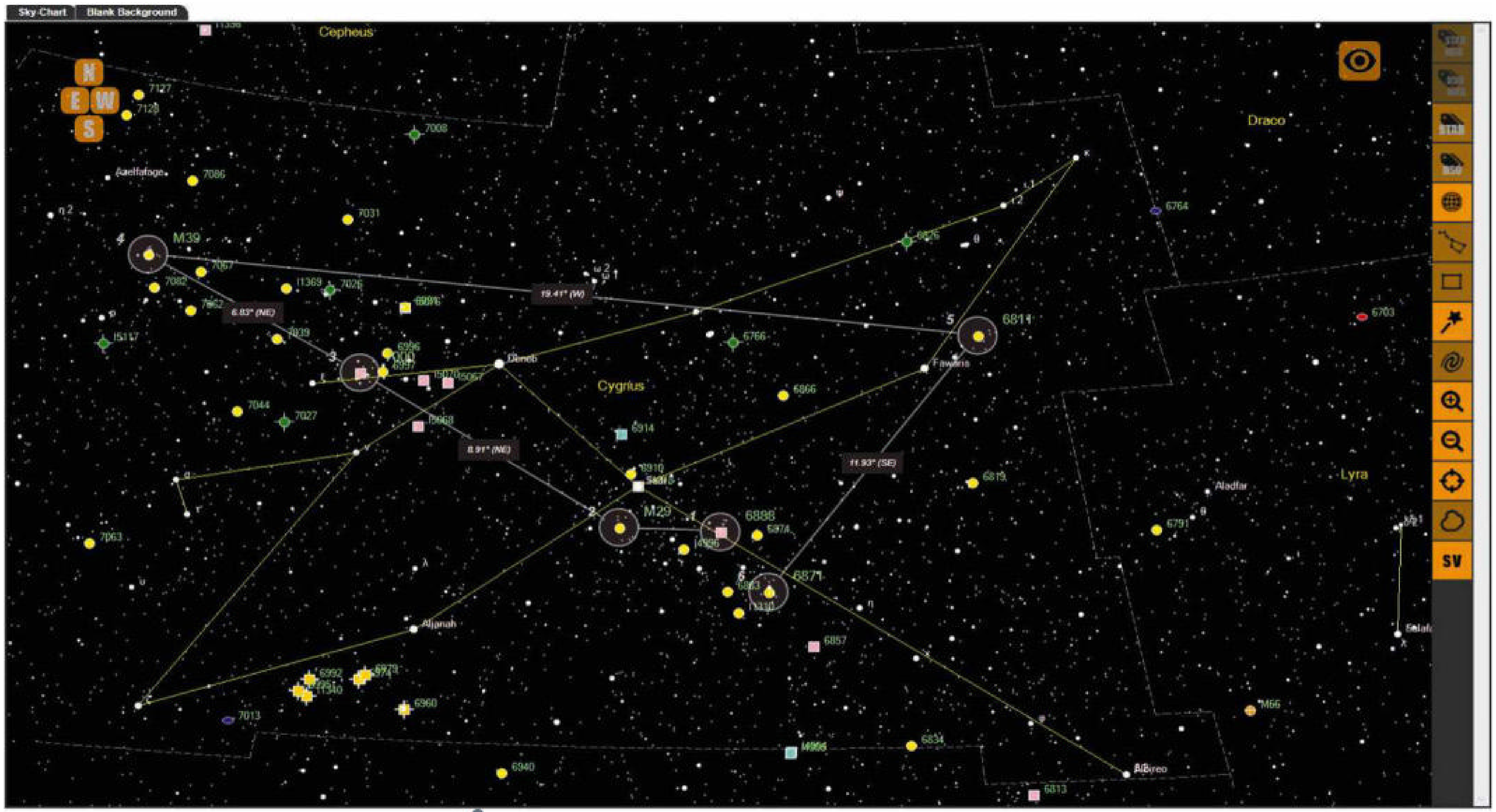
- **Price** €21
- **Delivery method** Download
- **Manual** Online PDF and videos
- **Updates** Available online
- **System requirements** Windows 10, Intel Core i5 processor or equivalent, 4GB RAM, ASCOM platform (latest), .NET 5.0 platform (not compatible with macOS)
- **Developer** Pindusoft
- **Email** via 'Contact' page on website (see below)
- **www.** starhopmaker.com

The fickle UK weather means that whenever there is an opportunity to observe, it is important to be prepared. However, despite the incredible number of celestial objects available for observation, it is all too easy to be caught out by an unexpected clear sky with no observing plan at the ready. In these circumstances Star-Hop Maker could be your best friend, as the software offers the opportunity to prepare a series of observing sessions in advance, with hops from one object to the next readily available one under the computer control of your mount. Star-hopping is already a popular, tried and tested method for moving from one known celestial object – like an easily recognisable star – to a more tricky target. By automating each hop, the Star-Hop Maker program takes this process to a new level.

Star-Hop Maker is available as a 110MB download with both a 30-day free trial version and a paid-for version that is licensed for use on two computers. Note that it is only available for PC computers and there is no macOS version of the app. A free Android app is available that can access star hops generated by the desktop version from your Google Drive account, although we were unable to test this as we didn't have a suitable smartphone available. We found the installation of the main program on both our Windows 10 desktop PC and laptop PC proved to be fast and straightforward.

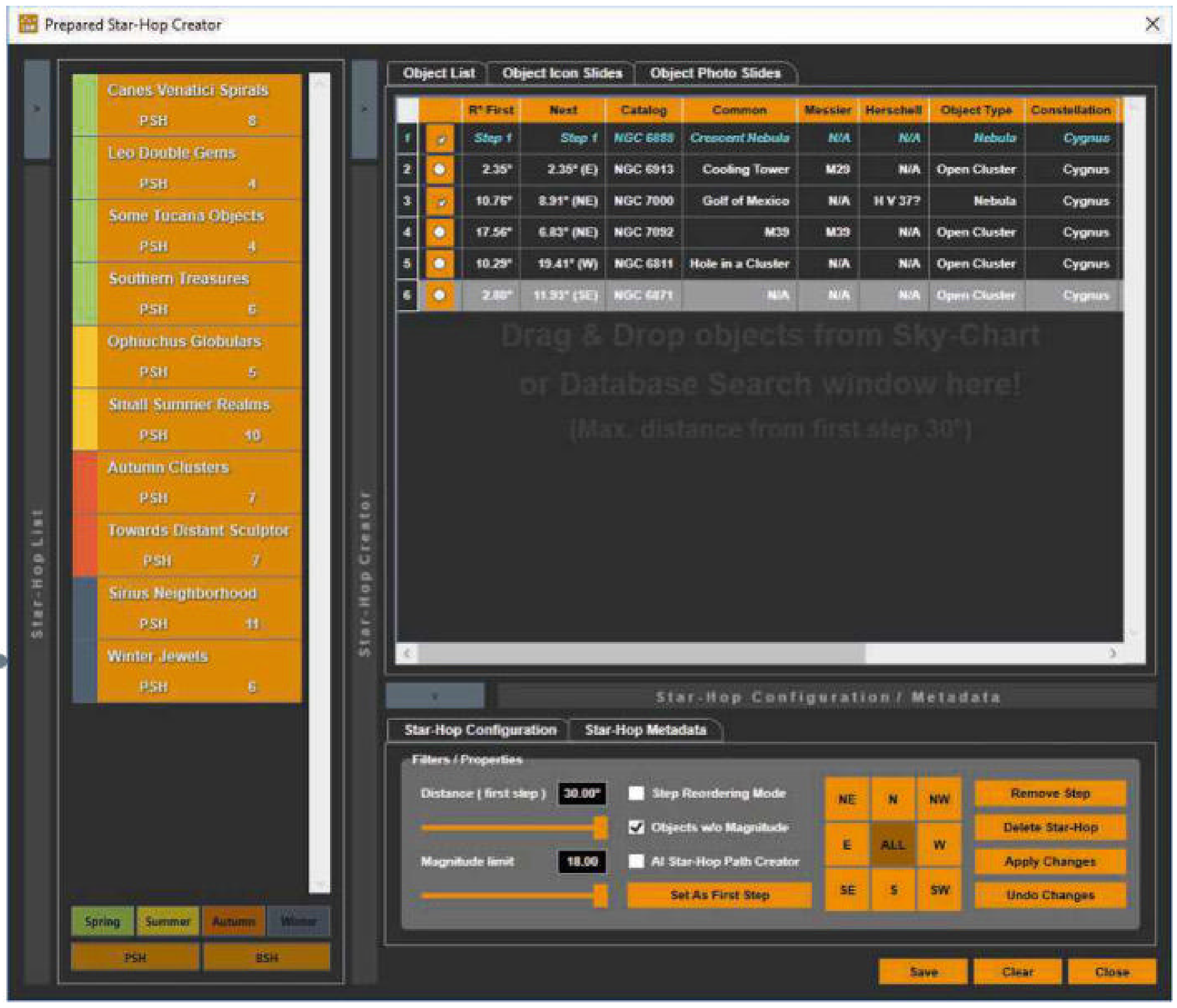
Setting your location

Before the software can be used, there is a little housekeeping to be performed so that the program knows something about your observing location and equipment. Your location can be conveniently entered using an interactive online map of the world to pinpoint where you observe from, or if you know your latitude and longitude you can enter these measurements directly. Equipment choices include ▸



Star-Hop Maker plan

With the final object selections made, the 'Sky-Chart' is automatically annotated with an overlay showing the individual hops. You can change the hop order by enabling the 'Reordering mode' and dragging the objects to a different position in the list or by dragging the 'Sky-Chart' circles to a new object position.



Prepared lists of objects to hop to

Once the results of the database searches have been tabulated, you can choose which of the available objects you would like to include in your Star-Hop Maker session by dragging and dropping them individually or en masse into the 'Prepared Star-Hop Creator' window. You can then choose the first object that you want to observe.

Object catalogues

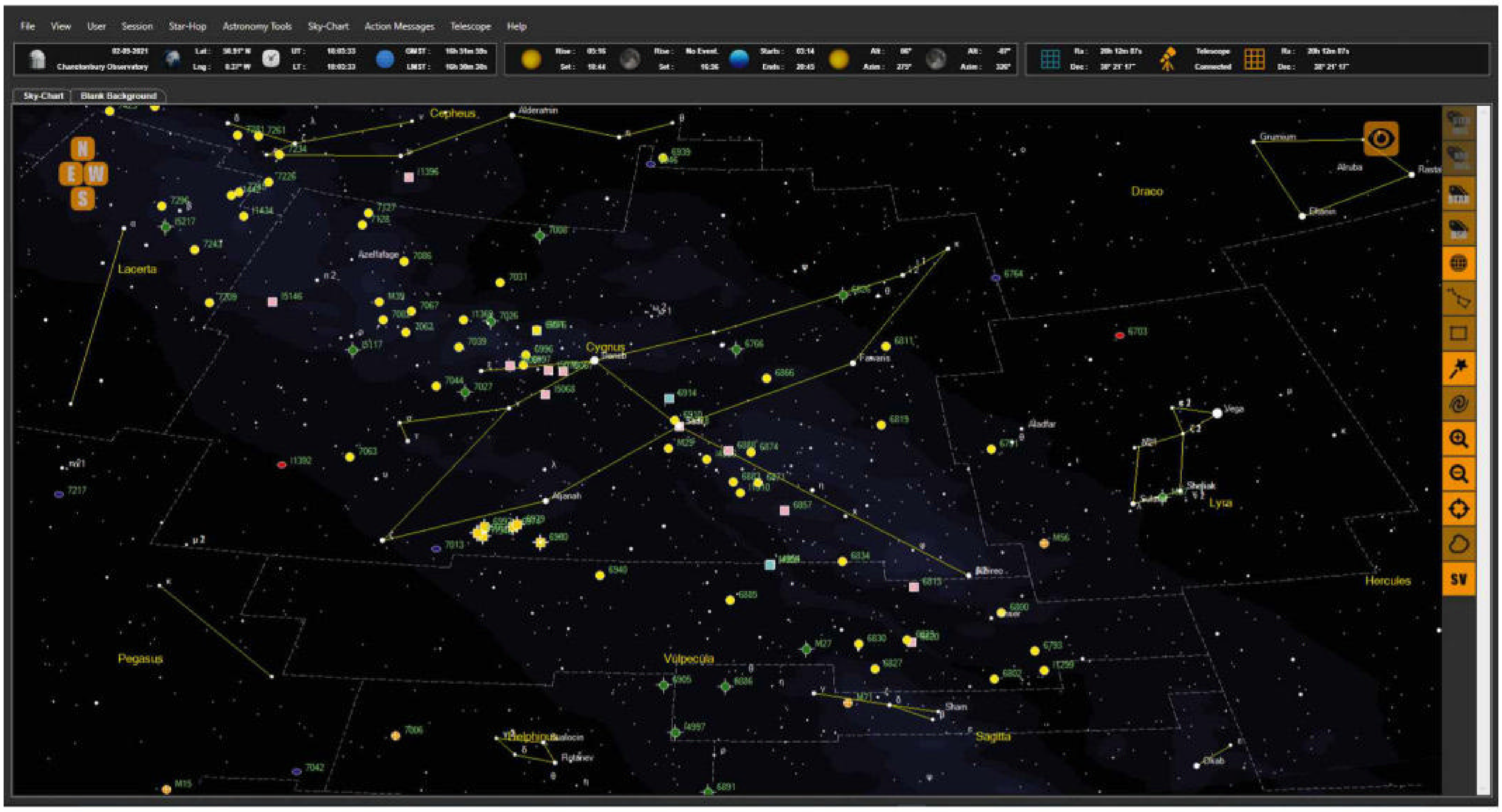
The software includes the 'NGC', 'IC', 'Messier' and 'Herschel' deep-sky object databases for you to select from, as well as 'Search Criteria' for 'Single', 'Double' or 'Variable Stars'. Searches are further refined by the season, constellations, object type, object properties and magnitude – so there is no shortage of objects to hop to.

▸ your telescope, binoculars, eyepieces, a Barlow lens, a focal reducer and filters. You can also select the driver for your mount so that automated slews to your selected object can be carried out. We used an ASCOM driver for our review and this worked flawlessly. (ASCOM is an industry-standard interface that allows different pieces of astronomical equipment to communicate with each other.)

A typical Star-Hop Maker generation session is started by producing a new 'Session' file from the 'Session' tab in the top menu and choosing a suitable name for it. This process stores a range of useful data about the session for examination, analysis and archiving later on. 'Object' selection follows and there are two types of Star-Hop to choose from: a 'PSH' (Prepared Star-Hop), which makes use of the program's search functions to produce a list of candidates; and a 'BSH' (Blind Star-Hop), which operates by allowing you to choose each object manually until the session is complete. We concentrated on the 'PSH' process as this allowed us to test the effectiveness of the search functions.

A raft of useful resources

Several deep-sky catalogues and star catalogues are included, and searches can be refined using the supplied tools to zero-in on the types of celestial object that you wish to observe. With your search



A feature-packed sky chart

As well as being an important part of the Star-Hop Maker process itself, the 'Sky-Chart' is a very useful standalone resource for researching the night sky and it has a reasonably good complement of search features. 'Stars' can be explored by 'Constellation', while 'Deep-sky Objects' can be searched by 'Messier', 'NGC' or 'IC' catalogue numbers, and there is a quick 'Constellation' chooser for a general search. With the 'Sky-Chart Photo Viewer' enabled, if you rest the mouse cursor on a deep-sky object, it will automatically download a black and white image from the SDSS (Sloan Digital Sky Survey) image database with a table of useful data alongside including rise, transit and set times for reference.

If you hold down the 'Alt' key and drag a box over a region of the night sky, it produces a dialogue box that lists the stars and other objects within the box, although this feature didn't always work first time. Because the image and other data have to be collected from an online server, it can sometimes take several seconds of apparent inactivity before the data box appears.

Although not a photorealistic view of the night sky, we found this 'Sky-Chart' feature very useful for planning our Star-Hop Maker sessions.

Star-Hop Maker control screen

The final step in a Star-Hop Maker observing session is to load the 'Star-Hop Runner' window, which allows you to hop from one object to another using the 'First', 'Last', 'Next' and 'Previous' buttons to navigate through your prepared list. The software automatically commands your mount to move to the selected object.

Observing log

There is a very useful and simple to use 'Observation Log' feature included with the software. This is particularly quick to fill in, as many of the usual observing notes are either already completed for you or can be selected from a range of typical choices by a single click of the mouse.

preferences set, the databases are queried and the software generates a list of objects meeting your criteria, presenting the results in a table format. The numerous columns within the table contain useful information about each object, including a 'smiley face' icon – ranging from a sad face through to a beaming smile – which is an indicator of how low or high the altitude of a target is, and therefore the best observing conditions. Useful black and white images accompanying each object will help you to decide on the final observing session list.

With the final list populated, the 'Sky-Chart' changes to an annotated version with all your chosen objects encircled and joined by straight lines indicating the order in which the observing session will run. If you want to alter the hop order, you can do so either by dragging objects in the table to a different position or dragging the circles on the chart to a different object. Furthermore, you can add additional objects to the Star-Hop plan by holding down the 'Alt' key while dragging a box around the area in which the new object(s) reside to produce a list of objects within the boundary box that you can select and then drag onto the existing list.

Finally, you run the 'Star-Hop Runner' module, which is automatically populated with the objects from your list and the observing session begins! Star-Hop Maker is suitable for all levels of experience, from beginners to seasoned observers, and it particularly comes into its own when it's coupled with a Go-To mount.

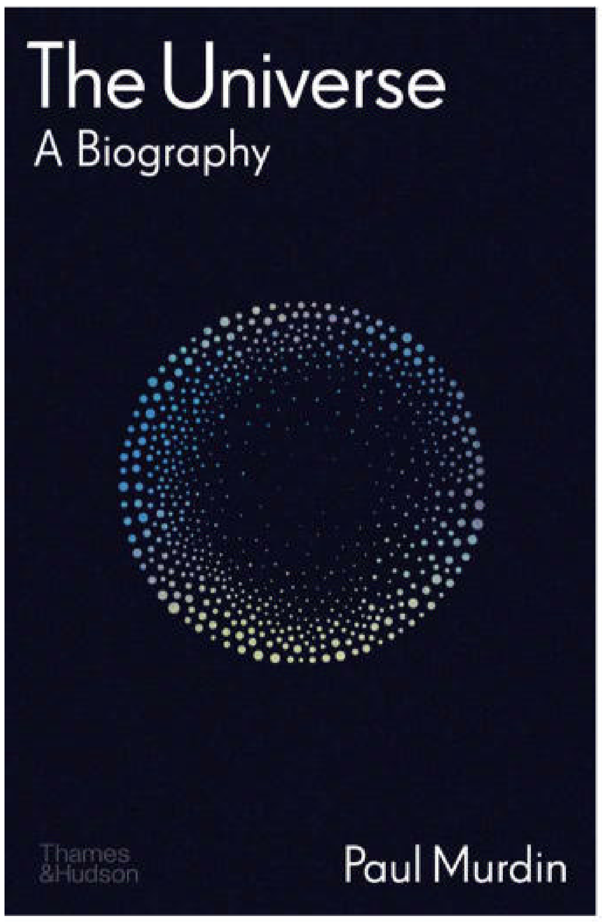
VERDICT

Ease of use	★★★★☆
Extras	★★★★☆
Features	★★★★½
Functionality	★★★½☆
Installation	★★★★★
OVERALL	★★★★½

KIT TO ADD
1. A Windows 10 PC or laptop.
2. A suitable ASCOM-driven Go-To mount.
3. A visual or imaging telescope.

New astronomy and space titles reviewed

BOOKS



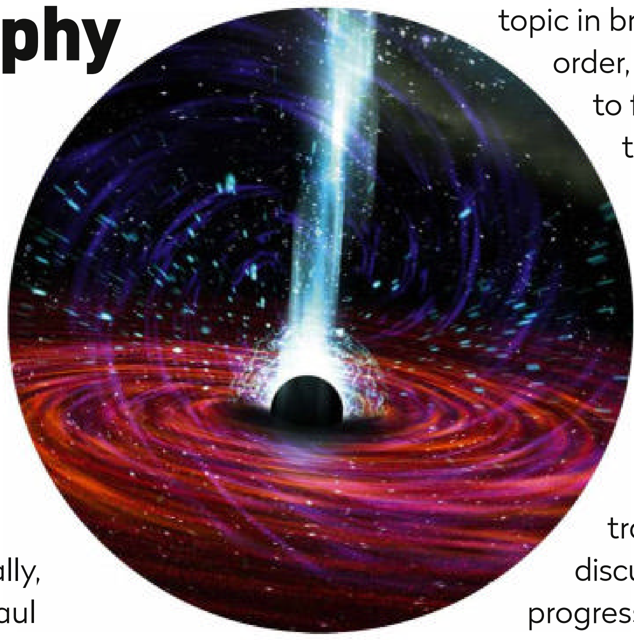
The Universe: A Biography

Paul Murdin
Thames and Hudson
£25 ● HB

Tackling the life story of the entire Universe is a fairly daunting prospect, for the prospective author (and, potentially, for the reader), but Paul Murdin's marvellous new book pulls it off in style.

With some 13.8 billion years to cover, the book moves along at a brisk pace. After an initial chapter outlining the fundamental evidence that the Universe was born and has evolved over time, the bulk of the book progresses broadly forwards in time while diminishing in scale. From the broad cosmological questions of the early chapters, we move forward to the formation of our Galaxy, the life cycles of stars and the origins of planets before finally coming up to date with the story of Earth. Despite the familiarity of this approach, I was pleased that Murdin still finds room to include entire chapters that cover topics that are often skated over, such as the emergence of structure from the Big Bang and the importance of planetary migrations.

Above all, it's the wealth of knowledge on display that impresses. A long career at the forefront of astrophysics (including the co-discovery of Cygnus X-1, the object that dragged black holes from the realm of theory into the remit of observational astronomy) provides Murdin with copious experience of the past half century of research, out of which he judiciously picks and chooses his stories, evidence and examples. This results in a refreshing perspective and some unusual lines of evidence that explore roads less travelled in other popular accounts.



▲ The author draws on his experience of discovering a black hole source

While each chapter tackles a specific topic in broadly chronological order, it's often necessary to follow these threads to a present-day conclusion for the sake of narrative coherence. To help the reader navigate, crossheads at the top of each right-hand page, track the period being discussed as each chapter progresses. It's a clever innovation, albeit one that takes a little getting used to. Minimalist illustrations for each chapter opener and a pair of plate sections provide some visual reference, but it's Murdin's text that takes centre-stage, and rightly so, as it's a model of concision and clarity. ★★★★★

***Giles Sparrow** is a science writer and a fellow of the Royal Astronomical Society*

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Interview with the author
Paul Murdin

What do we know about the birth of the Universe?

We can see the relic radiation of the Big Bang itself – the Cosmic Microwave Radiation – and we can handle some of what was made in the Big Bang before that time: material containing hydrogen (such as water). I'd say we are on firm ground talking about the first second of the Universe and afterwards. What happens in that time can be described in terms of well-established physics: gravity, atomic and nuclear physics, thermodynamics etc. Before the first millisecond or so, it becomes increasingly unclear because the relevant physics is particle physics, which is still being developed. Also, some sort of physics underlies the rapid expansion of the Universe: the details are almost unknown, except for generalities like the 'cosmological constant'. And before inflation, who knows? There is more to do!

Which Solar System bodies most deserve to be explored?

Dried out Mars and smoggy Titan. Saturn's satellite, Titan, is almost unexplored, but it has a bearing on the important question of how life originated. Mars may be Earth's future, Titan is Earth's past.

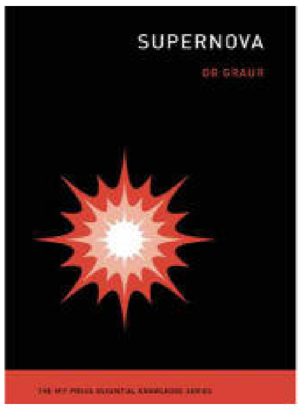
What are astronomy's big challenges?

Astronomy has progressed in spurts sparked by new instrumentation, but these are larger and more expensive. The world can now afford a space telescope, a global radio astronomy array, a Mars sample return mission and a gravitational wave antenna, but soon it will have to choose only one new instrument at a time. How will it make that choice?

***Paul Murdin** is an astronomer and former president of the European Astronomical Society*

Supernova

Or Graur
MIT Press
£13.99 ● PB



In *Supernova*, part of an MIT (Massachusetts Institute of Technology) book series, Or Graur explores the history and science behind these phenomena. As a researcher in the field, he is well-positioned and covers a lot in what was once a niche subject area, but which now has relevance to a broad swathe of astronomy and cosmology.

It begins with a brief history of supernovae observations, from ancient records to modern telescopes, followed by a bit of background science. We then learn how these phenomena tell us about the history of the Universe, our planet and maybe even life. It finishes with currently unanswered questions and what the future holds for the field of research.

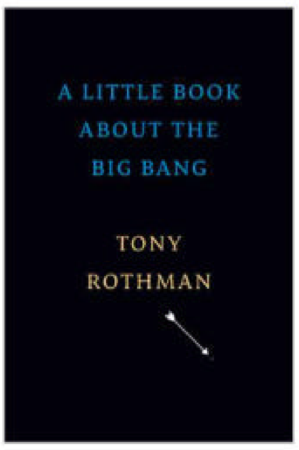
The book is fairly factual and succeeds in meeting the remit of the series to provide 'foundational knowledge', though it is hard to find the author's own voice if you prefer a personal touch. Interspersed through the text are references to endnotes. Most are further reading and those that contain additional bits of information get a bit lost, which is a shame as there's some useful context included.

There's no maths, but some of the figures are technical and suit a reader comfortable with graphs. This isn't a book for beginners: the basics are covered, but sometimes oddly placed (for example, parsecs aren't defined until Chapter 6), but there is a glossary. It's a good choice for someone who knows a little about the subject and wants more detail. ★★★☆☆

***Chris North** is Ogden Science Lecturer and STFC Public Engagement Fellow at Cardiff University*

A Little Book About The Big Bang

Tony Rothman
Harvard University Press
£19.95 ● HB



Cosmology is said to be the subject where physics and philosophy meet. It asks the really big questions about the origins of our Universe, its composition and evolution and why things are the way we see them today. The answers to these cosmological questions are often hotly disputed, and new theories are being developed and discoveries are being made almost daily. Indeed, to some of those questions pertaining to the birth and evolution of the Universe, the only answer is that we just don't know... yet.

This book aims to guide both laymen and experts through the latest scientific thinking on the subject. Author Tony Rothman, a former physics teacher at Harvard, Princeton and New York universities, explains complex ideas clearly with useful analogies, some simple diagrams and very little mathematics, but there is no time to relax as he goes at a quick pace.

Each chapter is short but densely packed, so you really need to concentrate. The four forces of nature, relativity, inflation and the expansion of the Universe, dark matter and dark energy, universal crunches and bounces, Planck units, quantum gravity, multiverses and metaphysics are all dealt with in rapid succession.

Frustratingly, but perhaps understandably, as the book is aimed at both novices and seasoned cosmologists, when things get too tough, or where knowledge ends and we enter into areas of speculation, the author breaks off abruptly.

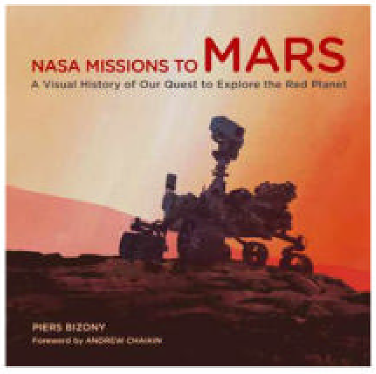
This book may look small in size but, much like Doctor Who's TARDIS, on the inside it is so much bigger. ★★★★☆

***Jenny Winder** is an astronomy writer and broadcaster*

NASA Missions to Mars

PACKED WITH FACTS

Piers Bizony
Motorbooks International
£35 ● HB



"There is life on Mars," science fiction writer Ray Bradbury once quipped, "and it is us. We are the Martians!" Those words, uttered on the very day that NASA's Viking 1 spacecraft landed on the Red Planet in July 1976, furnished an early reminder that modern 'life' on Mars is entirely human-fashioned: robotic orbiters, landers, rovers and probes.

In the book *NASA Missions to Mars*, journalist Piers Bizony paints a beautiful portrait of this most Earth-like of worlds, capturing it through our past imaginations, our present knowledge and, tantalisingly, how it might become our next planetary home.

With a rousing introduction by *A Man on the Moon*'s Andrew Chaikin, the book traces humanity's romance with the Red Planet from Percival Lowell's 'canals' to HG Wells's monstrous tripods. It also mentions Orson Welles's notorious radio dramatisation of *The War of the Worlds*, which caused widespread panic about a Martian invasion when it was broadcast on Halloween night in 1938.

Supported by exquisite images, movie posters and photography, the book leads us through the realms of fantasy and science fiction into the stark realities of the Space Age and considers how each US-led mission has gradually peeled back the Red Planet's mysterious veneer.

Bizony shows us the Red Planet as it truly is: windswept, dry and inhospitable, yet still harbouring clues of a wetter, life-nurturing past. And though the search for life remains a central tenet of this book, *NASA Missions to Mars* also has the feel of an unrequited love story. For as Chaikin lyrically waxes in his intro, as a youngster he fell in love with the world next door. As did we all. ★★★★★

***Ben Evans** is a science writer and author of several books on human spaceflight*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Ocal Electronic Collimator

Price £169 • **Supplier** First Light Optics • **www.firstlightoptics.com**

Transform collimation into a quick and easy process using this device. Install the collimator on your telescope, connect it to your computer, then use the software to help you as you manoeuvre both primary and secondary mirrors into perfect collimation.

2 Altair 30mm Binoviewers

Price from £399 • **Supplier** Altair Astro • **Tel** 01263 731505 • **www.altairastro.com**

ADVANCED There's no more squinting through the eyepiece with this binoviewer, which splits the light from your scope into two eyepiece barrels. The prisms are an oversized 30mm, so they give a full view even with high-end eyepieces that have a wider field stop. It comes without eyepieces, but bundle deals are available.

3 ZWO ASIair Plus Smart Wi-Fi Controller

Price £289 • **Supplier** Widescreen Centre • **Tel** 01353 776199 • **www.widescreen-centre.co.uk**

This device makes controlling your astro-imaging setup a doddle by running all your power outputs and data inputs through one device, which can then connect to your computer. This new version comes with 32GB of storage and a faster read speed.

4 Men's Heat Holders Horten Hat

Price £11.99 • **Supplier** Heat Holders • **https://heatholders.co.uk**

Made from soft yarn and lined with a fur-like insulating fabric, this hat ensures you will be comfortable while also staying warm throughout the night. The hat is lined with thermal HeatWeaver fabric, while the outside comes in a variety of colours.

5 Wooden Astrolabe

Price €34.90 • **Supplier** Mapospheres • **www.mapospheres.eu**

Use this astrolabe to navigate the skies like they did in ancient times, or just keep it as a stylish display piece. Comes either pre-assembled or as a kit.

6 Rings Around You Saturn Necklace

Price £19 • **Supplier** Lucent Studios • **https://wearelucent.com**

A golden brass Saturn makes a charming centre piece to this necklace. The jewel of the Solar System is suspended from an 18-inch gold-plated chain.

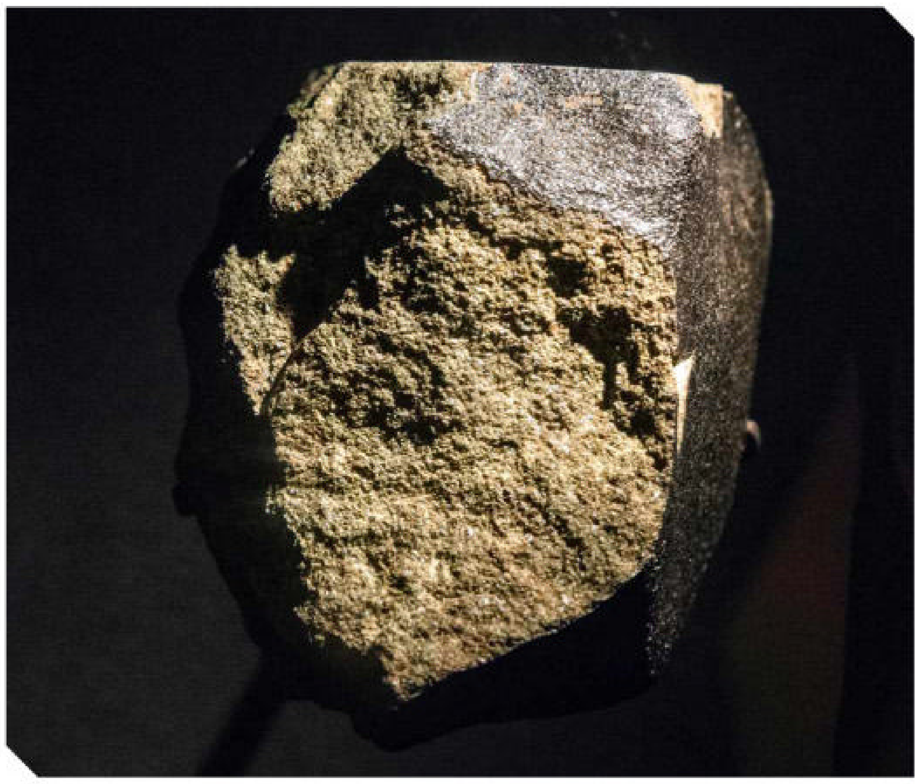
Melissa Brobby interviews Sara Motaghian

Q&A WITH A METEORITE ANALYST

Martian meteorites in the Natural History Museum are being used to develop software for the ExoMars 2022 rover to identify targets of interest on Mars

Why is the Natural History Museum's meteorite collection being used to test the spectral instruments for the Rosalind Franklin (ExoMars 2022) rover?
London's Natural History Museum houses one of the world's best meteorite collections; there are over 2,000 meteorites with a variety of histories. This gives us an amazing range of samples to select from, which best mimic the samples we see on Mars, and the ones we'd love to find.

We have set up an ExoMars testing set at the museum with instruments that emulate those on the ExoMars 2022 rover: AUP3 (Aberystwyth University PanCam Emulator), ISEM-E (infrared spectrometer emulator) and HRC-E (high-resolution camera emulator). These tests help us to understand how these instruments function, which is imperative to maximising the science we can do once on Mars. It allows us to develop software and best practices for use during the mission, which increases our chances of finding signs of life.



▲ **A meteorite from the collection at the Natural History Museum, London: a fragment of a meteorite that landed in Egypt in 1911 after being ejected from the Martian surface by a large asteroid or comet impact**

DIGITAL IMAGE LIBRARY/ALAMY STOCK PHOTO

Your team will be focusing on the use of multi-spectral imaging with the rover's PanCam instrument. What insights and features are you hoping this will show?
The PanCam filter set has been specifically designed to identify minerals of interest at the Oxia Planum, where the rover is due to land, which have high preservative qualities for biomarkers and organics. Essentially, these are materials that give us the best chance of finding evidence of life locked away in the subsurface, below the harsh radiation barrier. PanCam, HRC and ISEM will help us identify these locations for potential drilling on Mars.

As well as looking at Mars itself, the rover will be looking at meteorites that have fallen on Mars. What can we learn from them?
The meteorites found on Mars so far have mostly been iron meteorites. From the chemical and physical weathering of these, we can gain information about the climate and weathering in the region throughout the past. The size, abundance and distribution can help us infer information about the atmosphere and help improve our climate modelling for Mars through time. We can also gain meteoritic information more generally by looking at how the atmosphere has fragmented the meteorites.

Could the study of meteorites on Mars bring us closer to finding any history of life?
Absolutely. Chondritic meteorites on the surface of Mars are a potential delivery mechanism for carbon, hydrogen, nitrogen and amino acids to the surface (similar to some theories about Earth). The interaction of these meteorites as they enter the atmosphere can also synthesise hydrogen cyanide (HCN), which is a precursor to amino and nucleic acids. Chondritic meteorites weather in a very interesting way; they can weather from the inside out, leaving a shielded habitat on the inside with a lot of chemistry that's perfect for microbes. Researchers have even found chondrites in Australia's Nullarbor Plain that have been used by microbial life on Earth as a new habitat. These meteorites on Mars present many of the puzzle pieces required for life to evolve. Indeed, locations with a high abundance of these falls could have great potential for life.

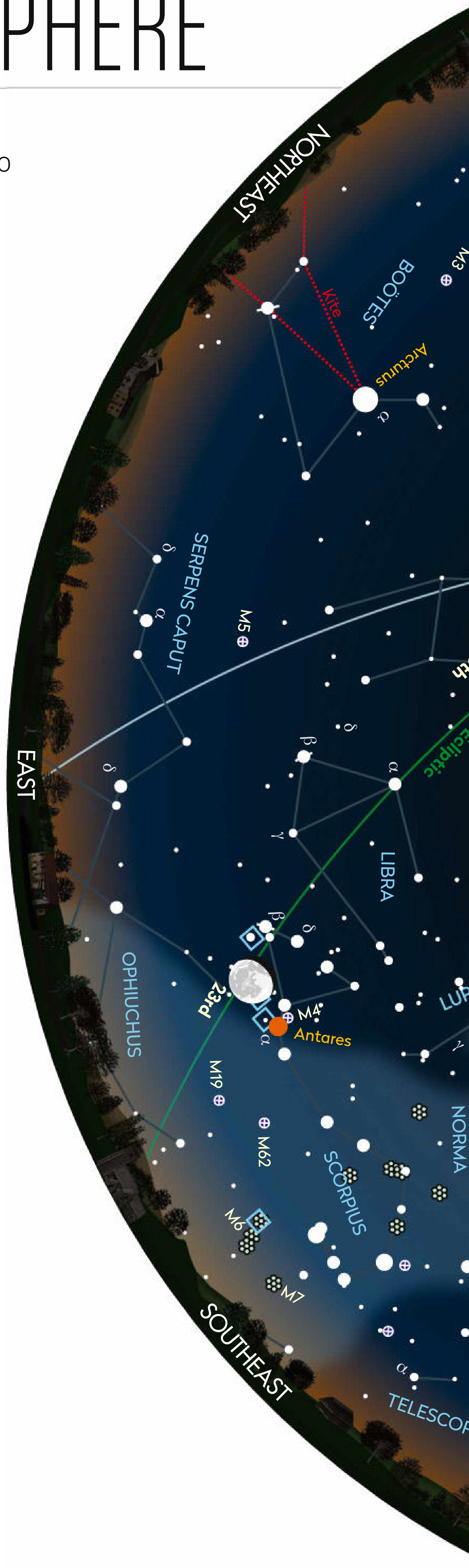
Sara Motaghian is a Space and Planetary Science PhD Researcher, and is part of the PanCam Science Team at London's Natural History Museum and Imperial College London

How does this work pave the way for future rovers to be sent to Mars to study meteorites?
Currently, we have found about 55 candidate meteorites on Mars, 15 recognised officially by the Meteoritical Society. Of those, only three are potential chondrites. So far, we haven't had an extensive amount of time to study meteorites on the surface, as they have primarily been opportunistic targets. With the automation of the spectral mapping and feature identification, we can identify these meteorites much more quickly, giving us sufficient time to study them before the rover moves on, hopefully giving us valuable insight. With the next phase of Martian exploration – which will be sample return, we can build the case to attempt to return one of these meteorites to Earth in the future.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

Enjoy five planets in the morning sky and get to know the double stars in Carina, the Keel



When to use this chart

1 Mar at 00:00 AEDT (13:00 UT)
15 Mar at 23:00 AEDT (12:00 UT)
31 Mar at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

MARCH HIGHLIGHTS

March finds all five naked-eye planets in the morning sky! Such a gathering evokes some impressive conjunctions. On 1 March, the eastern dawn sky finds Mercury and Saturn (along with a crescent Moon) fitting in a 5° circle. Two days later these two planets are only 0.6° apart.

Later in the month, Saturn has gained altitude to greet Mars and Venus. By the 29th Saturn has joined Venus, separated by 2°, along with a crescent Moon.

STARS AND CONSTELLATIONS

From down under we are fortunate to have the two brightest stars well placed to observe in the western evening sky in March. They are Sirius (Alpha (α) Canis Majoris) and Canopus (Alpha (α) Carinae). During March 1843, Canopus, briefly lost its 'number two' status in Canis Major, the Greater Dog, to another star in the same constellation – Eta (η) Carinae. This star's novae-like outburst made its brilliance rival that of Alpha (α) Centauri for the next 10 years, before it faded.

THE PLANETS

Uranus is the sole planet in the evening sky, but only visible low in the twilight sky. Mars and Venus continue to travel together in the morning, being visible from around 03:00. Saturn is rising before dawn, passing Mercury as March opens, going on to join Mars and Venus. Mercury concludes its morning apparition this month, being near Mercury and then Jupiter (on the 21st). Jupiter emerges from the Sun's glare mid-month, rising around the start of dawn by the month's end.

DEEP-SKY OBJECTS

This month a trip to Carina, the Keel, more precisely to a region south of the False Cross asterism. Upsilon (υ) Carinae (RA 09hr 47.1m, dec -65° 04') is a 3rd magnitude naked-eye double star. Its components, of mag. +3.0 and mag. +6.0, are a snug 5 arcseconds apart, but ideal for small telescopes using reasonable power (100x magnification). As a bonus, can you see another double star while looking at Upsilon Carinae (0.1° to the southeast)? It consists of a pair of 9th magnitude stars, 12 arcseconds apart.

Move 3.7° due west and discover the eye-catching star cluster NGC 2808 (RA 09hr 12.0m, dec. -64° 52'). This 6th magnitude globular has a compact, bright core, surrounded by a busy halo (with a diamater of 3 arcminutes) that drops off quickly at the edge. Mostly nebulous, only a few stars can be individually resolved.

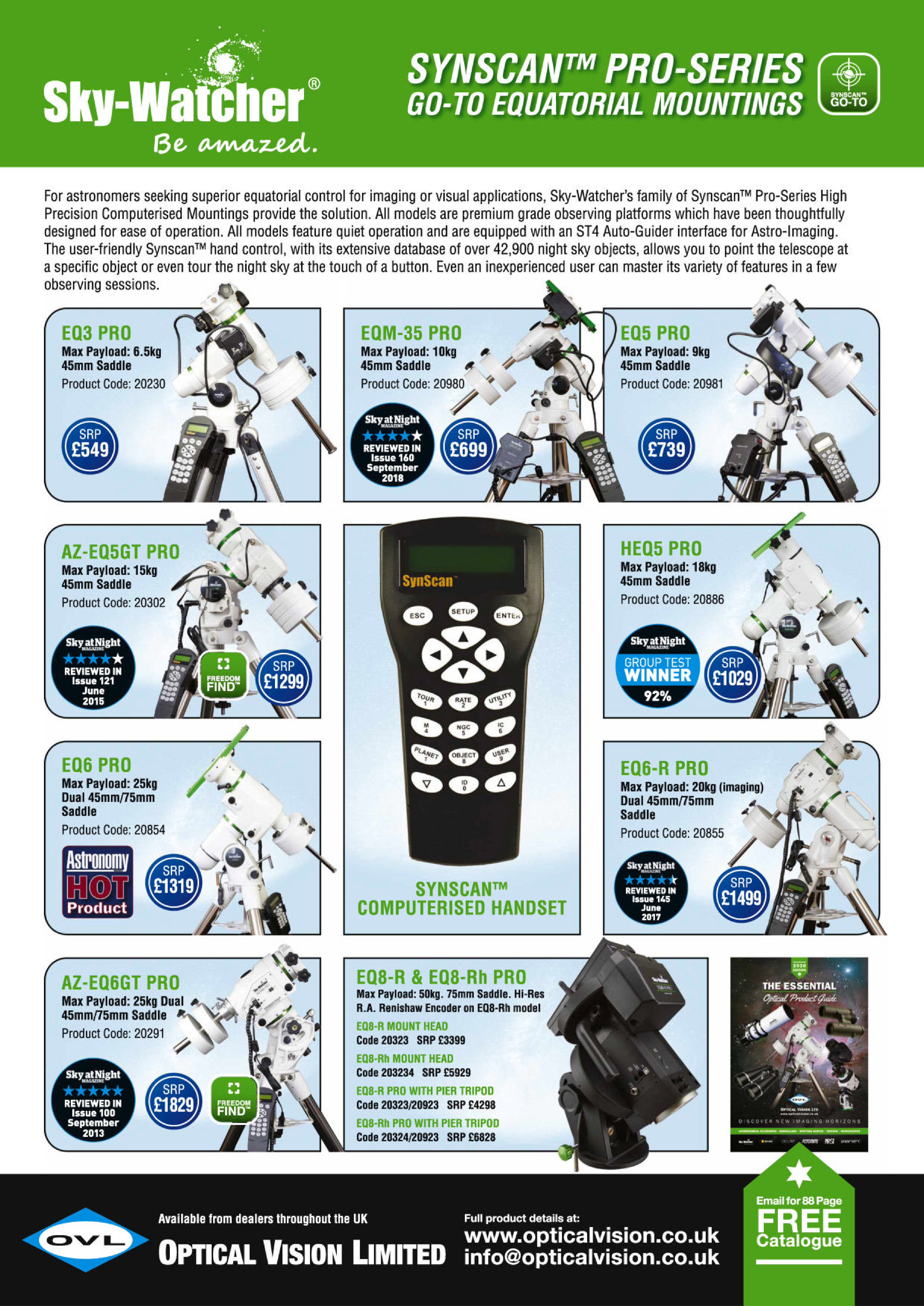
Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
LYNX
CANES VENATICI
Cor Caroli
M63
M94
M106
LEO MINOR
COMA BERENICES
GEMINI
Castor
Pollux
CANCER
M44
M35
11th
14th
17th
Sickle
LEO
Regulus
M65/66
M64
M86
M87
M60
M49
VIRGO
Spica
CANIS MINOR
Procyon
Betelgeuse
ORION
Rosette Nebula
Celestial Equator
SEXTANS
Alphard
CRATER
CORVUS
M104
Ghost of Jupiter
M48
M47
M50
MONOCEROS
Winter Triangle
M78
M42
Sirius
M41
CANIS MAJOR
Rigel
ERIDANUS
LEPUS
ANTLIA
HYDRA
M68
M83
PYXIS
PUPPIS
VELA
Eta Carina Nebula
CENTAURUS
Omega Cen.
CRUX
Jewel Box
Acrux
Hadar
Rigel Kent
False Cross
NGC 2516
NGC 2808
CARINA
Canopus
COLUMBA
MUSCA
CIRCINUS
Gamma Normids
Peak 14 March
PICTOR
VOLANS
LMC
CHAMAELEON
DORADO
MENSA
Tarantula Nebula
RETICULUM
HOROLOGIUM
CAELUM
Fornax A
TRIANGULUM AUSTRALE
APUS
OCTANS
South Celestial Pole
ARA
HYDRUS
SMC
47 Tuc
PAVO
Achernar
Peacock Star
TUCANA


Sky-Watcher®
Be amazed.
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SRP £1499
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